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Planetary Boundaries, Precautionary Principle and "Climate Engineering" from a Legal Perspective

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I. Planetary boundaries, science and law

With Article 20a of the Basic Law, the protection of the environment was anchored in constitutional law as a state task.[1] In this respect, the concept of planetary boundaries as defined by planetary system science, underlines that this state task is of existential importance for the continued existence of our planet and humanity.[2] This is because planetary boundaries formulate a science-based concept that describes the limits of ecological systems (absorption capacity), particularly for climate protection, but also for biodiversity, nitrogen and phosphorus input into the environment, land use change, freshwater use, ozone loss of the stratosphere and ocean acidification and its interactions.[3]

The core concern of the concept of planetary boundaries is to identify a "safe operating space" for humanity in which it can most likely live under stable Earth system conditions. It is true that ecosystems can compensate for impairments to a certain extent. However, once a certain level of stress is exceeded, disturbances and eventually irreversible damage occur.[4]

The starting point for determining planetary stress limits are scientific findings. In this respect, science has sophisticated methods to determine Earth system interactions, possible

[1] On this *Calliess*, Rechtstaat und Umweltstaat, 2001, p. 74 ff.
[2] In this regard, German Advisory Council on the Environment (SRU), Demokratisch Regieren in ökologischen Grenzen - Zur Legitimation der Umweltpolitik, Sondergutachten 2019, Rn. 9 et seq.
[3] Thus in 2009 *Rockström/Steffen/Noone/et al*, Nature 461 (7263), 472 ff; followed in 2015 by an update: *Steffen*, /Richardson,/Rockström/et *al*, Science 347 (6223).
[4] On this, German *Advisory Council on the Environment* (SRU), Demokratisch Regieren in ökologischen Grenzen – Zur Legitimation der Umweltpolitik, Sondergutachten 2019, Rn. 85 ff. (available online).

dysfunctions, thresholds and probabilities of occurrence. Nevertheless, despite all expertise, scientific uncertainties and prognostic ranges remain. The reasons for this include discontinuous processes that can occur, for example, when Earth system functions change in a non-linear or even abrupt manner when certain thresholds are reached - the exact location of which cannot be determined with certainty. In this respect, Earth system sciences speak of tipping points. The previsouly mentioned nine dimensions of planetary stress limits also interact with each other, which complicates the already complex prediction of possible damage processes and consequences.[5] If these tipping points are exceeded, irreversible environmental damage loom, which can result in a kind of "devastation scenario" and thus endanger the survival of humans and the environment.[6] Considering this, as well as the remaining scientific uncertainties outlined above, the concept of planetary boundaries draws on a science-based safety margin in determining the "safe operating space", specifically in the context of quantifying critical thresholds, which must be further concretized by political decision-makers.

Particularly in climate protection, the international climate protection goals laid out in the Paris Agreement, which call for limiting man-made global warming to well below 2°C compared to pre-industrial levels, but preferably to 1.5°C[7] , define a science-based global ecological limit.[8] The German Constitutional Court's climate decision of March 2021 also attaches a standard-setting significance to the agreement for defining the state goal of environmental protection in climate policy. In this respect, the BVerfG looks to the findings of climate science. With reference to the work of the Intergovernmental Panel on Climate Change (IPCC) as well as two expert reports of the interdisciplinary and advisory German Advisory Council on the Environment (SRU)[9] , the court convincingly links[10] to the findings of the Earth system sciences

[5] *German Advisory Council on the Environment* (SRU), Demokratisch Regieren in ökologischen Grenzen - Zur Legitimation der Umweltpolitik, Sondergutachten 2019, Rn. 57 ff. (available online).
[6] *German Advisory Council on the Environment* (SRU), Demokratisch regieren in ökologischen Grenzen - Zur Legitimation von Umweltpolitik, Sondergutachten 2019, Rn. 13 ff. (available online).
[7] Art. 2 para. 1 (a) of the Paris Convention of 12.12.2015, UN Doc. FCCC/CP/2015/10/Add.1 (Decision 1/CP.21), available at https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
[8] Intergovernmental Panel on Climate Change (IPCC), Global Warming of 1.5°C (2018), an English-language summary is available at https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf, p. 11 f. and 17 f.; on development *Schlacke*, Grenzwert oder Politikziel? Dogmatics and legitimacy of the 2°Celsius guard rail, in Dilling/Markus, Ex Rerum Natura Ius? Recht aus der Natur der Sache, 2014, p. 93 ff.
[9] On this advisory body, established as early as 1971, and its work, the contributions in: *A. Merkel (*ed.), Wissenschaftliche Politikberatung für die Umwelt, 1997.
[10] However, the author, who was a legal member of the SRU from 2008-2020 and contributed to the reports in this capacity, may be biased.

on planetary boundaries and the budget approach broken down by the SRU[11] to the European Union (EU) and Germany.[12] Even if the latter does not constitute a statement on climate-related planetary boundaries in the narrow sense of the term, but is rather to be classified as a normative statement on budget distributions between the global North and South, it has the function to apply an identified planetary boundary unilaterally to the jurisdiction of a nation state. In view of the actual complexity of the issue, this method seems appropriate and legitimate.[13]

Since the results of Earth system research show that in light of planetary boundaries measures are necessary, but cannot establish them concretely for the community of states or individual states, the science must be assessed normatively and politically in order to derive concrete conclusions.[14] As will be worked out in the following, there is indeed political discretion and scope for action in this respect. However, it is limited by a legal framework that can be controlled by the courts.

Especially through the safety margin mentioned above, the concept of planetary impact limits - as will be shown in this paper - contains a normative component that corresponds with the state task of environmental protection in Article 20a of the Basic Law and the preventative principle immanent in this norm: For both risk prevention and resource precaution seek to avoid[15] , as is the thesis here, critical thresholds or tipping points, which, if reached, threaten serious and irreparable damage to the environment.[16]

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[11] *German Advisory Council on* the Environment (SRU), Umweltgutachten 2020, Für eine entschlossenene Umweltpolitik in Deutschland und Europa, 2020, p. 37 ff. (available online); on the global approach already *Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (*WBGU), Kassensturz für den Weltklimavertrag - Der Budgetansatz, Sondergutachten, 2009, p. 9 ff.

[12] BVerfGE 157, 30, para. 16-21 as well as para. 33 ff. in connection with para. 122 and 216 ff.

[13] On this, *Köck*, ZUR 2017, 257 ff; in general, the contributions in: *Dreier/Willoweit* (eds.), Wissenschaft und Politik, 2010; *Wischmeyer*, Nachhaltige Gesetzgebung und Sachverständigenberatung, in: Kahl (ed.), Nachhaltigkeit durch Organisation und Verfahren, 2016, p. 253 ff.; crit. *Vierhaus*, NVwZ 1993, 36 ff; *Voland*, NVwZ 2019, 114 (119); against *Buser*, DVBl. 2020, 1389 (1394 f.); *Kahl*, JURA 2021, 117 (124).

[14] *Köck*, ZUR 2017, 257 ff; *Schlacke*, Grenzwert oder Politikziel? Dogmatik und Legitimität der 2°- Celsius-Leitplanke, in Dilling/Markus (eds.): Ex Rerum Natura Ius?, 2014, p. 93 (96 f.).

[15] See here only *Appel*, Staatliche Zukunfts- und Entwicklungsvorsorge, 2005, p. 299 f.; *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 176 ff.

[16] *Calliess*, ZUR 2019, 385; similarly on the determination of planetary boundaries or ecological impact boundaries as a mix of knowledge-based and precautionary principle already *Köck*, ZUR 2017, 257 f.; agreeing on the relevance of tipping points *Meyer*, NJW 2020, 894 (897 f.) as well as *Buser*, DVBl. 2020, 1389 (1392).

II. Concretisation of the precautionary principle in law

1. Starting Point

Above all, in the form of the aforementioned safety margin, the concept of planetary boundaries contains a normative component that corresponds with the state objective of environmental protection in Article 20a of the Basic Law and the[17] precautionary principle immanent to this norm.

In its sustainability strategy, the German government correctly describes the planetary boundaries as "ultimate constraints" for political decisions.[18] Nevertheless, there is a gap between scientific findings and the political promise to commit to the planetary boundaries as guard rails for sustainable action on the one hand, and the level of ambition of the adopted government strategies and programs, including the necessary concrete measures to be taken, on the other. This gap widens as soon as it comes to their binding implementation in law and their enforcement in everyday life. With regard to the German Climate Protection Act, the Federal Constitutional Court has addressed this gap with the construct of "intertemporal safeguarding of freedom" and formulated requirements for the political actors.

A significant reason for this gap in political action is that even the concept of planetary boundaries, given the complexity of Earth system science, cannot provide exact "scientific evidence" of when exactly a threshold and tipping point is crossed. At this point, the findings of earth system science must be assessed normatively and politically. In doing so, the political level must operate with the concepts of scientific uncertainty and insecurity typical of a risk society. In this framework, the safety margin formulated by the earth system sciences - according to my core thesis - represents the decisive connecting factor for the political coupling with the precautionary principle under environmental law.

2. Legal basis

The word "protects" in connection with the formulation "also in responsibility for future

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[17] *Calliess*, Rechtsstaat und Umweltstaat, 2001, pp. 114 ff. and 181 f.
[18] German Sustainable Development Strategy – New Version 2016, Federal Government, p. 12, available at https://www.bundesregierung.de/resource/blob/2196306/455740/260a9307085b9c7ef7543672f2147fe8/2017-06-20-langfassung-n-en-data.pdf?download=1.

generations" in Article 20a GG includes contents of the precautionary principle as well as the principle of sustainable development.[19] This is underlined in a historical and systematic interpretation by the Unification Treaty. Article 34 of the Unification Treaty makes it the task of the legislature "to protect the natural foundations of human life, taking into account the preventive, polluter and cooperation principles, and to promote the balance of ecological living conditions at a high level, or at least at the level achieved in the Federal Republic of Germany". According to its Article 45 (2), the Unification Treaty continues to apply as federal law even after the execution of accession. Although it does not have the rank of constitutional law, it has a "special dignity" as former treaty law, on the basis of which it continues to have a higher-ranking binding effect that must be observed.[20] Within the framework of the state's fundamental rights obligations to protect the individual, not only the prevention of danger but also risk prevention is recognised.[21] The precautionary principle is explicitly standardised in European environmental law in Article 191 (2) sentence 2 TFEU. The Commission and the ECJ even regard it as a general legal principle of all Union law beyond European environmental law .[22] In addition, the democratic legislator has anchored and concretised the precautionary principle in many German and European laws. The leading laws in this respect are immission control law, nuclear law, genetic engineering law and chemicals law.[23]

3. From hazard prevention to risk prevention

In view of the consequences (including the unintended side-effects) of industrialisation, scientific progress and the resulting new technologies, the entire legal system - this is currently only most evident in environmental and climate protection law - is constantly confronted with new challenges. The law is thus faced with the task of ensuring rational, risk-adequate and efficient control of this scientific and technological development, corresponding to the state's

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[19] This is also the prevailing opinion in the literature: *Bernsdorff*, NuR 1997, 328 (332); *Steiger*, in Arbeitskreis für Umweltrecht (ed.), Grundzüge des Umweltrechts, 2nd edition 1997, marginal no. 87 ff; *Murswiek*, in Sachs (ed.), GG, 9th edition 2021, Art. 20a marginal no. 32 ff; *Kloepfer*, DVBl. 1996, 73 (78); *Waechter*, NuR 1996, 321 (326); *Di Fabio*, Voraussetzungen und Grenzen des umweltrechtlichen Vorsorgeprinzips, in: Kley/Sünner/Willemsen (eds.), FS Ritter, 1997, p. 807 (812, 814).

[20] Thus *H. H. Klein*, DVBl. 1991, 729 (732); *Kloepfer*, Umweltrecht in der deutschen Einigung, 1991, p. 34 ff.

[21] On all this *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 179 ff.

[22] COM (2000) 1 final, 12; on this *Appel*, NVwZ 2001, 395 ff; in detail *Arndt*, Das Vorsorgeprinzip im EU-Recht, 2009, p. 80 ff; *Calliess*, in: Calliess/Ruffert (eds.), EUV/AEUV Kommentar, 6th ed. 2022, Art. 191, para. 28 ff. with further references.

[23] On this, *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 182 ff; overview of the specialised case law in *Köck*, Die Entwicklung des Vorsorgeprinzips im Recht - ein Hemmnis für Innovationen zum nachhaltigen Wirtschaften?, in: Hansjürgens/Nordbeck (eds.), Chemikalienregulierung und Innovationen zum nachhaltigen Wirtschaften, 2005, p. 85 (96 ff).

task of security. The crisis of the governance by law in the risk society[24] illustrates that the tried and tested legal system must in part tread new paths: While security was essentially defined as the absence of dangers - brought about by the state instrument of hazard prevention - until around the mid-1970s[25] , since then the question has been raised whether and, if so, to what extent security also encompasses the absence of risks or the mitigation of risks - brought about by state risk prevention[26] .

Generally, environmental legislation, parallel to the history of the development of environmental law[27], is modelled after the traditional basic structures of administrative police law and its forms in commercial law. Accordingly, the polluter-pays principle in environmental law also adopts the attribution triad of danger, causal connection and liable disturber, inherent to police law.[28] The existence of a danger is determined by the knowledge of facts from which, by way of rule of experience and subsequent prognosis, damage to a protected legal asset can be predicted.[29] The "knowledge" of a potential damaging event, based on general rules of experience, is therefore at the centre of effective safety assurance[30] . The greater and more serious the latter is, the lower the probability requirements demanded for the danger judgement; the mere possibility of a damage occurrence, however, is never sufficient for the assumption of a danger.[31] The classical hazard prevention outlined in this way as "damage prevention" thus

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[24] Concept in *Beck*, Risikogesellschaft, 1986, p. 35 ff. and 300 ff., from a legal perspective *Köck*, AöR 1996, 1 ff.; *Wolf*, Zur Antiquiertheit des Rechts in der Risikogesellschaft, in: Beck (ed.), Politik in der Risikogesellschaft, 1991, p. 378 as well as in detail *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 2 ff. and 158 ff. with further references.

[25] Cf. only *Isensee*, Grundrecht auf Sicherheit, 1983, p. 26; *Di Fabio*, Risikoentscheidungen im Rechtsstaat, 1994, p. 30 ff; *Köck*, Grundzüge des Risikomanagements im Umweltrecht, in: Bora (ed.), Rechtliches Risikomanagement, 1999, p. 139 (144 ff).

[26] *Ipsen*, VVDStRL 48, p. 177 (186 ff.); *Murswiek*, VVDStRL 48, p. 207 (208 ff.); *Preuß*, Risikovorsorge als Staatsaufgabe, in: Grimm (ed.), Staatsaufgaben, 1994, pp. 523 ff; *Scherzberg*, VerwArch 1993, 484 ff; *Schmidt*, DÖV 1994, 749 ff; *Köck*, AöR 1996, 1 ff; *Grimm*, Die Zukunft der Verfassung, 1991, p. 197 ff.*Wahl/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, p. 13 ff; *Wolf*, Zur Antiquiertheit des Rechts in der Risikogesellschaft, in: Beck (ed.), Politik in der Risikogesellschaft, 1991, p. 378 (382 f.); *Köck*, Grundzüge des Risikomanagements im Umweltrecht, in: Bora (ed.), Rechtliches Risikomanagement, 1999, p. 139 (147 ff).

[27] *Kloepfer*, Zur Geschichte des deutschen Umweltrechts, 1994, p. 30 ff.

[28] *Di Fabio*, Risikoentscheidungen im Rechtsstaat, 1994, p. 30 ff.

[29] See only BVerwGE 45, 51 (57); *Kingreen/Poscher*, Polizeirecht, 11th edition 2020, § 8 Rn. 1 et seq.

[30] *Pitschas*, DÖV 1989, 785 ff; *Preuß*, Risikovorsorge als Staatsaufgabe, in: Grimm (ed.), Staatsaufgaben, 1994, p. 523 (527); in detail *Ladeur*, Das Umweltrecht der Wissensgesellschaft: von der Gefahrenabwehr zum Risikomanagement, 1995, p. 9 ff, 69 ff.

[31] See only *Kingreen/Poscher*, Polizeirecht, 11th edition 2020, § 8 marginal no. 6 f.; critical of the prevailing approaches to the definition of probability *Darnstädt*, Gefahrenabwehr und Gefahrenvorsorge - eine Untersuchung über Struktur und Bedeutung der Prognose-Tatbestände im Recht der öffentlichen Sicherheit und Ordnung, 1983, p. 35 ff.

initially became the cornerstone of environmental law.[32]

However, where there are no experiments confirming the causality of damage and no scientific evidence, a probability sufficient under police law can no longer be established for lack of the necessary certainty of assessment. However, if certain indications point to an abstract possibility of damage, the transition between danger on the one hand and risk on the other is reached. [33]

In certain cases, in view of this lack of knowledge, it will also be possible in the future to proceed according to the law of hazard prevention according to the *trial and error method.* However, this method is only appropriate for potential damage that is *reversible.* If, on the other hand, certain projects, techniques and interventions in the environment can be reasonably expected to have irreversible effects from the outset, the *trial and error method* also faces the aforementioned constitutional limits arising from the state's duty to protect. In addition to the task of averting hazards, which could be carried out on the basis of proximity calculations and short, linear causal processes, the complex task of risk prevention - mediated by the precautionary principle - has subsequently emerged. [34]

4. Content and requirements of the precautionary principle

In the literal sense, prevention primarily means the creation of a stock for the future by doing without in the present: natural resources, which are becoming increasingly scarce, must be used sparingly in the present in order to preserve them as a stock for future generations in the interest of their viability. At the same time, this resource precaution serves the purpose of conserving environmental resources in the interest of their future use by not exhausting the ecological limits. In this way, "free spaces" are to be preserved in the form of "future habitats" for humans and nature, as well as in the form of reserves for pollution and ecological resilience. [35]

However, precaution is also designed to cope with risk situations defined by uncertainty and

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[32] *Wolf*, Zur Antiquiertheit des Rechts in der Risikogesellschaft, in: Beck (ed.), Politik in der Risikogesellschaft, 1991, p. 378 (382 f.); *Di Fabio*, JURA 1996, 566 (568).
[33] *Di Fabio*, JURA 1996, 566 (568); *Wahl/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, p. 86.
[34] For a detailed discussion of all this, see *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 153 ff.
[35] *Lübbe-Wolff*, Präventiver Umweltschutz - Auftrag und Grenzen des Vorsorgeprinzips im deutschen und im europäischen Recht, in: Bizer/Koch (eds.), Sicherheit, Vielfalt, Solidarität, 1997, p. 47 (55 f., 68 f.) with further references.

insecurity (risk prevention). In expansion of the concept of danger oriented on the concept of probability, risk can be defined as a situation in which, in the case of an unhindered course of events, a condition or behaviour possibly leads to an impairment of legal assets. The decisive factor is therefore the replacement of the concrete, sufficient probability by the mere possibility, the abstract concern, of the occurrence of damage.[36] In this way, the object of risk prevention becomes danger instead of damage, with the aim of avoiding the misjudgement of a danger.[37] The decisive consequence of the extension of the classic danger prevention model by the precautionary model is shifting the permissible time of intervention for state measures to a prior point. [38]

If damage is either completely uncertain or its realisation can be practically ruled out with certainty, then - as the BVerfG has also ruled - the democratically elected legislature can decide that this so-called residual risk is acceptable.[39] This political decision only becomes legally relevant insofar as there is an obligation that the residual risk is always kept as low as possible according to the latest state of science and technology.[40]

5. Material and procedural requirements of the precautionary principle

The scope of the precautionary principle cannot be unlimited in a free constitutional state. In this respect, it is first necessary to concretise the precautionary principle in a way that conforms to the rule of law. The aim must therefore first be to prevent precaution from becoming a "shot in the dark".[41] Against this backdrop, an objective, exhaustive determination of all information relevant to the precautionary measure is required in the context of risk assessment.[42] For precaution, an abstract potential for concern is sufficient, i.e. a theoretical - in contrast to pure speculation, however, based on scientific plausibility reasons - initial suspicion which,

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[36] *Murswiek*, Die Staatliche Verantwortung für die Risiken der Technik, 1985, pp. 81, 86; *Ipsen*, VVDStRL 48, p. 177 (186 f.); *Wahl/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, p. 88; also *Darnstädt*, Gefahrenabwehr und Gefahrenvorsorge - eine Untersuchung über Struktur und Bedeutung der Prognose-Tatbestände im Recht der öffentlichen Sicherheit und Ordnung, 1983, p. 36 ff.
[37] Cf. *Hansen-Dix*, Die Gefahr im Polizeirecht, im Ordnungsrecht und im Technischen Sicherheitsrecht, 1982, p. 21; *Scherzberg*, VerwArch 1993, 484 (497 f.); *Wahl/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, p. 76; *Köck*, AöR 1996, 1 (19).
[38] For more details, see *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 154 ff.
[39] BVerfGE 53, 30 (59); BVerfGE 49, 89 (137 ff.).
[40] In-depth *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 167 ff.
[41] *Ossenbühl*, NVwZ 1986, 161 (166).
[42] *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 207 ff.

however, must not yet be empirically solidified or even scientifically proven in the sense of a majority opinion.

a) Risk identification with the aid of science and technology

In a first step, therefore, it must be scientifically determined and continuously researched what the respective risk potential consists of and how extensive it is (preliminary scientific risk determination). Based on relief and concern criteria - with scientific help - formulas can be developed that serve to determine this initial suspicion. Based on such formulas, concrete rules for a precautionary approach to uncertainty can be formulated.[43]

b) Risk assessment

This risk identification must be separated from the risk assessment, i.e. the evaluative consideration of the cause of precaution characterised by the abstract concern potential.[44] Within this framework, it must be decided whether the respective risk potential is tolerable or not and with which measures it should be countered according to the sliding scale of safety dogmatics (hazard-risk-residual risk) (preliminary political risk assessment). This assessment is first and foremost the responsibility of the legislator, who, within the framework of the aforementioned constitutional requirements, has a scope for assessment, evaluation and prognosis.

c) Precautionary measure

aa) Concept of Protection

With regard to the precautionary measure to be taken, it is then possible - taking into account the principle of proportionality - to identify different levels of interference with the economic freedom guaranteed by fundamental rights. In this respect, it is not a matter of preventive bans with licensing requirements from the outset, but often of generating information accompanying

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[43] Cf. the proposals of the *German Advisory Council on the Environment* (SRU), Vorsorgestrategien für Nanomaterialien, Sondergutachten 2011, Rn. 430 ff. (available online).

[44] Cf. on the whole *Murswiek*, VVDStRL 48, p. 207 (217 ff.); *Wahl/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, pp. 109; *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 214 ff; similarly *Scherzberg*, VerwArch 1993, 484 (499 ff.); Communication of the European Commission on the applicability of the precautionary principle, COM (2000) 1 final of 2.2.2000, p. 14 ff.

the preliminary risk assessment, which is suitable for clarifying the existing uncertainty. Following from this, it is a matter of creating transparency and enabling traceability in the event that a substance in a product that was initially considered harmless turns out to be dangerous due to new findings.[45]

Moreover, the precautionary principle requires decisions-makers in state institutions to act in a forward-looking manner, which includes special consideration of risks and their short- and long-term effects.[46] Furthermore, the state is constitutionally obliged to preserve economic space for newcomers (i.e. those companies that start their activities and thus burden the environment for the first time) as well as future generations in accordance with the precautionary principle.[47] This requirement corresponds to the approach of "intertemporal safeguarding of freedom" in the BVerfG's climate decision. Finally, in the case of complete or partial irreversibility of environmental pollution, the precautionary principle requires decision-makers to act with foresight, which includes special consideration of long-term risks.[48] Accordingly, the legal assessment of environmental harm by pollutants must not only focus on the current effects, but also take into account their summation over years.[49]

Measured against these normative requirements, Article 20a of the Basic Law (as well as the fundamental rights) in conjunction with the precautionary principle results in a judicially controllable mandate to act, in the course of which the German state institutions (analogously, this applies to those of the EU via Article 191 TFEU) must visibly steer away from the ecological stress limits and avert a (further) overstepping of the ecological boundaries by means of a suitable, effective as well as long-term, coherent and legally binding protection concept.[50]

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[45] *Calliess/Stockhaus*, DVBl. 2011, p. 924 ff.; in detail on the example of nanomaterials, *Sachverständigenrat für Umweltfragen* (SRU), Vorsorgestrategien für Nanomaterialen, Sondergutachten 2011, Rn. 438 ff. (available online).
[46] *Murswiek*, NVwZ 1996, 222 (225); *Kloepfer*, DVBl. 1996, 73 (77, 78); *Steiger*, in Arbeitskreis für Umweltrecht (ed.), Grundzüge des Umweltrechts, 2nd edition 1997, para. 103.
[47] *Waechter*, NuR 1996, 321 (326); *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 182 ff.
[48] *Murswiek*, NVwZ 1996, 222 (225); *Kloepfer*, DVBl. 1996, 73 (77, 78); *Steiger*, in Arbeitskreis für Umweltrecht (ed.), Grundzüge des Umweltrechts, 2nd edition 1997, para. 103.
[49] *Reiter*, Entschädigungslösungen für durch Luftverunreinigungen verursachte Distanz- und Summationsschäden, 1998, pp. 48 ff. and 133 ff.; also *Feldhaus*, UPR 1987, 1 (5); *Wahl/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, pp. 133 f..
[50] For a detailed discussion, see *Calliess*, Rechtsstaat und Umweltstaat, 2001, pp. 125 ff. and 235 ff.

bb) Proportionality in consideration of conflicting interests ("opportunities and risks")

It is precisely the dynamic, precautionary character of the environmental state[51] , which is expressed not least in the understanding of its constitutional basis in Article 20a of the Basic Law as well as the precautionary principle concretising and optimising it, that it almost inevitably comes up against the rights, legal goods and legal principles united under the principle of the rule of law designed to ensure permanence and legal certainty. In this respect, the Federal Constitutional Court states:

"*The requirement of the rule of law, when viewed in conjunction with the general presumption of liberty in Article 2 (1) of the Basic Law in favour of the citizen, requires that the individual be protected from unnecessary interference by public authority. If a legislative intervention is indispensable, the means must be suitable for achieving the legislative objective and must not impose an excessive burden on the individual.*" [52]

This expresses that (also) every state precautionary measure must be proportionate. It is therefore no coincidence that the principle of proportionality is unanimously described in practice and literature as the limit of the precautionary principle.[53] However, if done in an abstract and undifferentiated manner, this insight is of little help. This is especially true because the starting point of the proportionality test under the rule of law remains unclear.[54]

Against this background, it is above all the positioning of the proportionality test to fundamental rights that is important, which thus mark the actual constitutional limit of the precautionary principle. Accordingly, it follows from the modern understanding of fundamental rights that every law legitimising interference is in turn examined for its suitability, necessity and appropriateness, in order to carry out the encroachment on fundamental rights as sparingly as

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[51] On the emergence of the term *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 30 ff.
[52] BVerfGE 55, p. 159 (165); E 17, p. 306 (313 f.).
[53] BVerwGE 69, p. 37 (44); EU Commission, Communication from the Commission on the applicability of the precautionary principle, COM (2000) 1 final, 2.2.2000, p. 20 f.; *Sendler*, JuS 1983, 255 (256 f.); *Ossenbühl*, NVwZ 1986, p. 161 (167 f.); *Rengeling*, Umweltvorsorge und ihre Grenzen im EWG-Recht, 1989, p. 37 ff.; *Trute*, Vorsorgestrukturen und Luftreinhalteplanung im Bundesimmissionsschutzgesetz, 1998, p. 72 ff; *Di Fabio*, Voraussetzungen und Grenzen des umweltrechtlichen Vorsorgeprinzips, in: Kley/Sünner/Willemsen (ed.), FS Ritter, 1997, p. 807 (828 ff.); *Lübbe-Wolff*, Präventiver Umweltschutz, in: Bizer/Koch (ed.), Sicherheit, Vielfalt, Solidarität, 1997, p. 47 (63 ff.).
[54] Instructive on this *Köck*, Die Entwicklung des Vorsorgeprinzips im Recht - ein Hemmnis für Innovationen zum nachhaltigen Wirtschaften?, in: Hansjürgens/Nordbeck (eds.), Chemikalienregulierung und Innovationen zum nachhaltigen Wirtschaften, 2005, p. 85 (103 ff.).

possible.[55] Accordingly, part of the literature correctly points out that the principle of proportionality can only develop its control effect where individual legal positions are affected, especially when state precautionary measures interfere with fundamental rights.[56] The attempt to further substantiate the principle of proportionality in general terms with regard to precautionary measures under uncertainty does not lead anywhere.[57] However, these authors leave it at this correct statement. In particular, they overlook the necessity of anchoring the proportionality test for precautionary measures in the fundamental rights test. If one wants to determine the limits of the precautionary principle and thus the constitutional limits of the environmental state at a relatively higher level of abstraction, fundamental rights and the proportionality test based on them provide a sufficiently concrete framework for examination. From this follows which legislative and subsequently administrative limits the rule of law sets for the environmental state.

In a concrete case, the balancing has to take place within the framework of a multipolar proportionality test, which can admittedly only be outlined here.[58] The prohibition of excess of defensive rights on the one hand and the prohibition of inadequate protection of the state obligation to protect on the other hand form a kind of corridor[59] , within which the legislature has the leeway required by the separation of powers to weigh and balance the conflicting interests. This results in the following structure for judicial review of the legislative distribution of freedom: Its starting point lays at the respective legal positions of the multipolar constitutional law system. For each of them, the first and second step of the proportionality test must be carried out individually. Thus, for environmental polluters, the first and second step of

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[55] BVerfGE 55, p. 159 (165); E 17, p. 306 (313 f.); *Wendt*, AöR 1979, 414 ff; *Di Fabio*, Voraussetzungen und Grenzen des umweltrechtlichen Vorsorgeprinzips, in: Kley/Sünner/Willemsen (eds.), FS Ritter, 1997, p. 807 (829).

[56] *Trute*, Vorsorgestrukturen und Luftreinhalteplanung im Bundesimmissionsschutzgesetz, 1998, p. 77; *Rengeling*, Umweltvorsorge und ihre Grenzen im EWG-Recht, 1989, p. 56 ff; *Di Fabio*, Voraussetzungen und Grenzen des umweltrechtlichen Vorsorgeprinzips, in: Kley/Sünner/Willemsen (eds.), FS Ritter, 1997, p. 807 (833). It is nevertheless surprising that the above-mentioned authors nevertheless discuss the principle of proportionality in abstract terms in advance. In general, on the concretised fundamental rights connecting factor of the principle of proportionality: *Wendt*, AöR 1979, 414 (461 ff.); *Schnapp*, JuS 1983, 850 (854 f.).

[57] *Ossenbühl*, NVwZ 1986, p. 161 (167); *Lübbe-Wolff*, Präventiver Umweltschutz, in: Bizer/Koch (eds.), Sicherheit, Vielfalt, Solidarität, 1997, p. 47 (64 f.).

[58] In depth *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 577 ff.

[59] The views of *Canaris*, JuS 1989, 161 (163 f.); *Jarass*, AöR 1985, 363 (382 ff.); *Scherzberg*, Grundrechtsschutz und "Eingriffsintensität", 1990, p. 221 f.; *Isensee*, Das Grundrecht als Abwehrrecht und als staatliche Schutzpflicht, in: Isensee/Kirchhof (ed.), HStR Bd. IX, 3rd ed. 2011, § 191, marginal no. 303 f. such a model; *Hoffmann-Riem*, DVBl. 1994, 1390 (1384 f.) explicitly speaks of such a corridor; likewise *Cremer*, Freiheitsgrundrechte, 2003, p. 310 ff; *Brönneke*, Umweltverfassungsrecht, 1999, p. 274 ff. constructs - under the same premises - a star-shaped model.

the prohibition of excess under their defensive lrights must be examined. In the case of the party affected by pollution, the first and second steps of the prohibition of insufficient protection under protective laws must be examined.

Correspondingly, the same must be done for the public interest concerns affected (embodied in Article 20a of the Basic Law in the case of environmental protection relevant here). At the third stage of the multipolar proportionality test, all three test strands converge. Figuratively speaking, this means that the walls of the corridor on the third level are no longer considered independently of each other - one-dimensionally, as it were - but that the corridor now only arises in a multi-dimensional manner in the first place. This is done through the instrument of a multipolar interest balancing, in the framework of which the interrelationships between the legal positions of the multipolar constitutional law relations are taken into account and brought into balance.[60]

Based on these specifications, the significance of the various interests to be weighed in the legislative distribution of freedoms can be defined. It is recognised that parallel interests shift the weighting within the balancing process. Accordingly, the interests of the duty to protect fundamental rights (e.g. Article 2 (2) of the Basic Law) and the common good (e.g. Article 20a of the Basic Law) can be added up, provided they are identical in content, and thus strengthen a specific objective pursued with the state measure (e.g. air pollution control) as well as the interests it protects. The balancing determined in this way is a framework-like specification for the legislative development of a concrete protection concept, or - if a protection concept already exists - a yardstick for its judicial review and (possibly) further development or redesign.[61]

As a concretising component of the multipolar proportionality test, an alternatives test must be carried out[62] - viewing all legal positions involved: It opens up not only the state's scope for action, but also that of individual freedom. Thus, a variant can be compatible with the requirements of the prohibition of excess as well as with those of the prohibition of inadequacy. The alternatives assessment thus aims precisely at the described corridor between both prohibitions. It becomes an instrument of the overall balancing within the framework of the

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[60] In this regard, *Cremer*, Freiheitsgrundrechte, 2003, p. 314 ff. critically.
[61] *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 580 ff.
[62] In general, *Winter*, Alternativen in der administrativen Entscheidungsbildung: zugleich ein Beitrag zu einer Grundpflicht ökologischer Verhältnismäßigkeit, 1997.

multipolar proportionality test, which serves to establish practical concordance between the individual legal positions of the multipolar constitutional law system. For by bringing about flexibility, the alternatives test helps to find the "right balance" between favouring and burdening and thus to establish the balance of the distribution of freedom in the multipolar constitutional rights system.[63] In this context, for example, the authorisation of pilot projects as an alternative to bans can be expedient.[64]

III. Towards enviromental sustainability

1. Environmental sustainability and precaution through integration

The so called "*integration principle*" or "*cross-cutting clause*" of the EU enshrined in Article 11 TFEU offers a good example for legal pathways to achieve the goal of environmental sustainability. It reads as follows: "*Environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development*." According to the conception and intention of Article 11 TFEU, the integration clause is a significant instrument for implementing the principle of sustainable development in EU Law.[65] In conjunction with the Preamble and Article 3(3) sentence 2 TEU it implies even a general principle of sustainability for the EU.

Article 11 TFEU can be understood as a primary law requirement for conducting a strategic environmental impact assessment, which applies not only to individual measures, but also to policies, programs, plans and laws.[66] However, within the framework of Article 11 TFEU, the requirements of environmental protection must be balanced against conflicting interests (such as economic freedom and the principle of the welfare state).

In this regard, politics, and in particular the legislator, have a political margin of discretion in

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[63] *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 592 et sequ.; with concrete examples , see, Innovationsförderung durch Koppelung von Genehmigung und Alternativenprüfung?, in: Eifert/Hoffmann-Riem (eds.), Innovationsfördernde Regulierung, 2009, p. 221 sequ.

[64] *German Advisory Council on the Environment* (SRU), Capture, Transport and Storage of Carbon Dioxide, Statement on CCS 2009.

[65] *Calliess*, Die neue Querschnittsklausel des Article 6 ex 3c EGV als Instrument zur Umsetzung des Grundsatzes der nachhaltigen Entwicklung, DVBl. 1998, 559 et seq. and *German Advisory Council on the Environment* (SRU), Demokratisch Regieren in ökologischen Grenzen - Zur Legitimation der Umweltpolitik, Sondergutachten 2019, Nr. 270 et seq. and Nr. 309 et seq. (available online); in this sense as well European Commission, see document SEC (93) 785.

[66] *Appel*, in: Koch/Hoffmann/Reese (eds.), Handbuch Umweltrecht, 5th ed. 2018, § 2 para. 44.

implementing the provision. Nevertheless, when balancing environmental protection against conflicting economic and social interests, two specific aspects must be taken into account. Art.11's demands have to be implemented in conjunction with the goals of Article 191(1) and the precautionary principle in Article 191(2) TFEU.[67] In addition fundamental rights obligations that guarantee an "*ecological minimum subsistence level*" by respecting a "*safe operating space*" have to be taken into account. In the balancing process, this is further supplemented by a prohibition of insufficient means or actions ("*Untermaßverbot*") on part of the legislature.

Secondly, the concept of integration implies that environmental considerations cannot simply be disregarded.[68] Instead, they must be an integral part and visibly shape the content of the individual EU measure.[69]

Apart from these substantive requirements, the integration clause also has a procedural dimension, that demands effective monitoring of the fulfilment of the substantive side in European decision making and the Member States' implementation process[70] by institutionally established scrutiny mechanisms or "*watch dogs*". Article 11 TFEU has gained significance as environmental burdens have increased and the recognition has grown that environmental assets such as ecosystems, environmental media, and the climate are often closely interconnected, giving rise to strong interdependencies between various environmental sectors and issues.[71] The legislative scope of discretion in this respect is exceeded when a measure is visibly designed to the detriment of environmental protection. Such a measure, which is very likely to result in significant damage to the environment may not be adopted under Article 11 TFEU. A policy that crossed this boundary would be unlawful, as it would be in breach of Article 11 TFEU.[72]

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[67] *Calliess*, in: Calliess/Ruffert (eds.), EUV/AEUV, 6th ed. 2022, Art. 11 TFEU para. 14.
[68] See *Calliess*, DVBl. 1998, 559 (565 et seq.) as well as *Calliess/Dross*, ZUR 2020, 456, (461).
[69] *Hailbronner*, in: Calliess/Wegener (eds.), European Environmental Law as an Opportunity, 1992, p. 15 (20 et seq.); *Durán/Morgera*, Environmental Integration in the EU's External Relations, Chapter 1, Section 4.2.1; *Epiney*, EU Environmental Law, p. 162; *Appel*, in: Koch/Hoffmann/Reese (eds.), Handbuch Umweltrecht, 5th ed. 2018, § 2 para. 4 et seq.; *Scheuing*, EuR 1989, 152 (176 et seq.); *Kahl*, in: Streinz (ed.), EUV/AEUV, 3rd ed. 2018, Art. 11 TFEU, para. 17; contra *Nettesheim*, in: Grabitz/Hilf/Nettesheim (eds.), EU, 78th supplement January 2023, Art. 11 TFEU, para. 22, who also refers in para. 23 et seq. to European jurisdiction.
[70] On this already *Calliess*, Die neue Querschnittsklausel des Article 6 ex 3c EGV als Instrument zur Umsetzung des Grundsatzes der nachhaltigen Entwicklung, DVBl. 1998, p. 559 (566 f.).
[71] *Calliess/Dross*, ZUR 2020, p. 456 (461).
[72] In contrast, AG Geelhoed argues that Article 6 EC [now Article 11 TFEU] can only serve as a criterion for the legality of Community acts if environmental concerns have obviously not been taken into account or completely disregarded, Opinion in Case C-161/04, ECR 2006, I-7183, para. 59 (no decision in this case due to withdrawal).

This leads to the assumption that Article 11 TFEU has great potential for realising the ecological transformation of both of its addressees, the Union and its Member States. Nevertheless, it can be said that the *explicit* inclusion of an ecological clause in highly complex areas, such as economic policy, could be beneficial, in particular, considering the difficulty regarding the implementation and legal enforcement of Article 11 TFEU[73]. The implementation of goals is in the responsibilty of the Member States and too often lost in the complexity of the political process. Therefore, it is very welcome that as part of the European Green Deal, the European Commission has announced that it will work to strengthenefforts to ensure that existing legislation and measures relevant to the European Green Deal are enforced and effectively implemented.[74] If the proclaimed strategy of the European Green Deal is not to be lost in everyday politics, Article 11 TFEU must fulfil its potential for realising the transformation towards an ecological legal system. The provision points the way to an ecologically sustainable and thus **future-oriented economic policy** that makes environmental policy one of its integral parts and is aligned with the sustainability and viability of ecological systems. Ultimately, the contribution of Article 11 TFEU to the realisation of an "*ecological Union*" depends on how it is handled in practice.

2. Environmental sustainability and precaution through procedure

Even though there is further room for unfolding the potential of Article 11 TFEU, it is evident that there are already instruments and tools, which provide for an operationalisation of environmental principles, such as the reversal of burden of proof in the context of the precautionary principle.[75] If, however, an appropriate level of protection cannot be derived directly from scientific results in view of continuing uncertainties, there is a growing need to safeguard environmental sustainability by means of suitable procedural rules.

a) Lowering the standard of proof in the legislative precautionary measure

Procedural regulations shall ensure that the scope for assessment and evaluation given in the

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[73] Equally *Kahl*, in: Streinz (ed.), EUV/AEUV, Art. 11 TFEU, para. 50 et seq.; *Calliess/Dross*, Klimapolitik und Grundrechtsschutz, ZUR 2020, p. 461.
[74] European Commission, Communication from the Commission, The European Green Deal, COM(2019) 640 final, p. 4; On proposals for strengthening enforcement of European Environmental Law, see *SRU*, 2020, paras. 753-754.
[75] See on the precautionary principle *Calliess*, in Calliess/Ruffert (eds.), EUV/AEUV, 6th ed. 2022, Art. 191TFEU, paras. 28-37; See in detail *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 207 et seq.

gauging of scientific data and findings is disclosed. Above all, if the scientific risk assessment does not arrive at unambiguous evaluations, the decision-making procedure fulfils an important compensatory function; it must be "socially robust".[76] This is the only way to ensure social acceptance.[77] The precautionary principle is therefore also interpreted in the literature as a process requirement, in the course of which various procedural requirements are formulated.[78] In this respect, various aspects must be taken into account:

The question will often arise as to what should be done if the existing uncertainty cannot (yet) be determined due to a lack of sufficient research or cannot be resolved with the available means of investigation in view of an existing dispute between experts. If, as in the area of classical hazard prevention, the sufficient probability of the occurrence of damage must be proven, then the burden of proof lies with the potentially affected party of the risk or - corresponding to the state's duties to protect from Art. 20a GG and the fundamental rights - with the state.

Outside the legal discussion, for example in philosophy and environmental ethics, a general reversal of the burden of proof ("in dubio contra projectum") has therefore been demanded for certain risks.[79] From this point of view, the precautionary principle implies a reversal of the burden of proof. The problems of a general reversal of the burden of proof under the rule of law, in particular under fundamental rights, whose basic idea is similar in its absoluteness to the reservation of permission derived in part from the duties to protect under fundamental rights[80] , cannot be further discussed here. [81]

In contrast, the introduction of a rebuttable presumption of danger could be considered.[82] Within the framework of the abstract potential for concern, or the much-cited situation of non-liquidity, in which the existing uncertainty cannot be clarified with the available means of investigation, the precautionary principle acts according to the legal model of a rebuttable presumption of danger, which - as the Commission rightly states in its statement on the

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[76] In depth *Nowotny/Scott/Gibbons*, Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty, 2001.
[77] In detail *Grunwald*, Zur Rolle von Akzeptanz und Akzeptabilität in der Bewältigung von Technikkonflikten, in: Technikfolgenabschätzung Theorie und Praxis, 2005, p. 54 ff. 2005, 54, especially 58 ff.
[78] *Election/Appel*, Prävention und Vorsorge: Von der Staatsaufgabe zur rechtlichen Ausgestaltung, in: Wahl (ed.), Prävention und Vorsorge, 1995, p. 1 ff.
[79] *Jonas*, The Principle of Responsibility, 1984, p. 70 ff; *Böhler*, ZRP 1993, 389.
[80] VGH Kassel, NJW 1990, 336; VG Gelsenkirchen, ZUR 1993, 119 ff.
[81] *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 19 et seq. and 431 et seq. with further references.
[82] *Calliess*, DVBl. 2001, 1725 (esp. 1732 f.).

precautionary principle[83] - can lead to a reversal of the burden of proof.[84] Of course, for reasons of the rule of law, the requirements for the burden of proof must not reach the level of positive proof for the possibility or impossibility of harm.[85]

In order to shake this presumption, the entity causing the risk is required to present facts and prove, in the sense of a reasonable probability, that there is no threat of harm from its substance, manufacturing process or product. This puts the onus on the causer, from whose sphere the risk originates, with the consequence that the state institutions - starting with the legislator up to the administration deciding in the individual case (on the basis of the adopted law) - are relieved in this situation of uncertainty. Such a shifting of the burden of proof can be enacted by the legislator as law within the framework of its risk decisions for individual cases. It acts as an incentive for the risk causer to conduct their own impact research parallel to development research in order to rebut the legal presumption of danger in a - where necessary, set up specifically for this purpose - procedure in which the concerns of those affected by the risk are also taken into account.[86]

b) Transparency in the legislative and administrative process

Procedural regulations must ensure that the scope for assessment and evaluation given in the evaluation of scientific data and findings is disclosed. A transparent decision-making process requires that the entire range of scientifically justifiable risk assessments, from optimistic to pessimistic assumptions, be presented and alternative solutions be developed in the process of concretisation. Consideration of the entire spectrum of scientifically justifiable positions also includes minority opinions.[87] Only if precautionary measures are justified in a sufficiently transparent manner in the political process can a loss of credibility be avoided, which can result, for example, from adaptation to new findings. Therefore, in order to improve the political

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[83] COM (2000) 1 final. p. 24; in this respect *Rengeling*, DVBl. 2000, 1473 (1479 f.); in turn *Appel*, NVwZ 2001, 395 (396, 398).
[84] In detail *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 223 ff.; also *Arndt*, Das Vorsorgeprinzip im EU-Recht, 2009, p. 290 ff., 295 f., who assumes as a direct consequence of the precautionary principle only a reduction of the standard of proof, but not a reversal of the burden of proof, but sees such a reversal realised within the framework of the authorisation procedures under secondary law.
[85] *Rehbinder*, Grenzen und Chancen einer ökologischen Umorientierung des Rechts, 1989, p. 9 f.; *Ritter*, DÖV 2002, 641 (648 f.); in depth *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 223 ff.
[86] For more details on all this, see *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 223 ff. with further references; German *Advisory Council on the Environment* (SRU), Vorsorgestrategien für Nanomaterialen, Special Report 2011, marginal no. 438 ff. (available online).
[87] COM (2000) 1 final.

implementation of measures, the lack of scientific knowledge must be addressed. This requires a change in the political risk culture.[88]

c) Appropriate participation of social groups in the legislative and administrative process

In view of the political character of risk assessment, the decision-making process must not only be transparent, but must also allow for a plural discourse on values and therefore take place with the institutionalised participation of the representatives of social groups involved in public life.[89] It is crucial, however, that the political and the scientific-technical levels are appropriately linked with each other procedurally, so that each side can fulfil the function to which it is entitled. The institutionalised participation of social groups increases the political legitimacy of decisions and should ensure that a broad spectrum of risk assessment criteria is taken into account.[90]

d) Monitoring the implementation of the precautionary principle in the legislative and administrative process

If the protection of future generations required by Article 20a of the Basic Law is to be given practical significance, then the (constitution-amending) legislature is obliged to institutionalise the state's long-term responsibility flowing from it through regulated procedures and forms of organisation.[91] The obligation of procedural implementation, which is aimed at helping the substantive core of the norm to become effective, is essential especially in the case of those norms which - like Article 20a of the Basic Law - are only accessible to a limited extent to substantive concretisation.[92] In this sense, the procedure compensates for the indeterminacy of the content of a legal norm. A procedural concretisation of the provisions of Article 20a GG requires above all institutional precautions. A decisive political reason for this is the realisation that sustainability concerns have a comparatively weak standing in the system of electoral period and party democracy.

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[88] COM (2000) 1 final. For this purpose, using the example of nanomaterials, German *Advisory Council on the Environment* (SRU), Vorsorgestrategien für Nanomaterialen, Sondergutachten 2011, Rn. 438 et seq.
[89] Fundamental *Stern/Fineberg*Understanding Risk: Informing Decisions in a Democratic Society, 1996.
[90] *Hey*, Sustainability and Complexity: Institutional Innovations in the EU, in: Prittwitz (ed.), Institutional Arrangements in Environmental Policy, 2000, p. 85 ff; *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 463 ff.
[91] Likewise *Kloepfer*, DVBl. 1996, 73 (78); in detail *Gethmann/Kloepfer/Nutzinger*, Langzeitverantwortung im Umweltstaat, 1993, p. 35 ff.
[92] In this sense also *Steinberg*, NJW 1996, 1985 (1989, 1991).

In this respect, it is possible to build on existing institutions or establishing new ones.[93] For example, one could start with the administrative state and either use existing administrative decision-making structures in the interest of sustainability or entrust newly established administrative institutions with the protection of specific sustainability concerns.[94] Further possibilities open up with monitoring along the legislative process.[95] This monitoring can take place with the institutionalised involvement and participation of scientific policy advice in the political decision-making process.[96] Among others, a permanent committee to be set up by the Bundestag to examine the ecological consequences of laws and to assess the impact of technology[97] , an independent council of experts for future issues as well as similar models of an environmental council[98] , an ecological council[99] , a sustainability council[100] or also a council for intergenerational justice[101] are being discussed, each of which would have to be included in the decision-making processes as representatives of environmental concerns.

IV. Environmental sustainabitlity and precautionary principle in the context of planetary boundaries

1. Concretising requirements from Art. 20a GG in the light of the BVerfG's climate decision

The legal interface between the precautionary principle and planetary boundaries is first and foremost the state objective of environmental protection in Article 20a of the Basic Law.

Although this legal connection with regard to the precautionary principle is not developed with sufficient clarity by the BVerfG in the climate decision, the building blocks are laid out in the

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[93] Overview in *Calliess*, Nachhaltigkeitsräte, in: Kahl (ed.), Nachhaltigkeit durch Organisation und Verfahren, 2016, p. 275 (277 ff.).
[94] In detail *Ruffert*, DÖV 1998, 897 ff.
[95] *Calliess*, Nachhaltigkeitsräte, in: Kahl (ed.), Nachhaltigkeit durch Organisation und Verfahren, 2016, p. 275 (288 ff.); in-depth *Sachverständigenrat für Umweltfragen* (SRU), Demokratisch regieren in ökologischen Grenzen - Zur Legitimation von Umweltpolitik, Sondergutachten 2019, Rn. 323 ff. (available online).
[96] *Gethmann/Kloepfer/Nutzinger*, Langzeitverantwortung im Umweltstaat, 1993, p. 38 f.; cf. also the - tendentially critical - overview of the existing institutionalised expertise by *Vierhaus*, NVwZ 1993, 36 ff.
[97] Cf. for example Kuratorium für einen demokratisch verfassten Bund deutscher Länder, Verfassungsentwurf, pp. 44 f., 114, according to which in Art. 45 a technology impact committee is to be appointed by the Bundestag, which is to be granted the rights of a committee of enquiry.
[98] *Steinberg*, Der ökologische Verfassungsstaat, 1998, p. 345 f.
[99] Cf. *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 515 ff.
[100] *Calliess*, Nachhaltigkeitsräte, in: Kahl (ed.), Nachhaltigkeit durch Organisation und Verfahren, 2016, p. 275 (277 ff.).
[101] *German Advisory Council on the Environment* (SRU), Demokratisch regieren in ökologischen Grenzen - Zur Legitimation von Umweltpolitik, Sondergutachten 2019, Rn. 340 ff. (available online).

climate decision and can be elaborated as follows: Via the Climate Protection Act, which concretises Article 20a of the Basic Law and in this way acquires quasi-constitutional status[102], the BVerfG states that the legislature has a duty, flowing from the state objective of Article 20a of the Basic Law, to distribute the "necessary reductions in CO2 emissions up to climate neutrality over time with foresight and in a manner that protects fundamental rights". In view of this, the current climate protection law must be improved.[103] For if the reaction to climate change is too hesitant until 2030, much stricter measures would have to be taken in the period until 2050, so that comparatively severe restrictions on freedom may occur in the future.[104] The objection that "the global character of climate and global warming precludes a solution to climate change by one state alone" is convincingly answered in the sense of the open constitutional state conceived by the Basic Law, so that Art. 20a GG obliges international cooperation, but also - and this is very significant in view of the climate protection goals[105] - in the "mutual trust" of states to "implement agreed solutions". An obligation to dynamise protection is also correctly derived from Article 20a of the Basic Law.[106] Since Article 20a of the Basic Law, with its focus on "future generations", provides the standard of the precautionary principle, the BVerfG could have examined on this basis, both in the context of a procedural review and a substantive review of justifiability[107] , whether the legislature has fulfilled its resulting duties of care.[108]

2. Concretising requirements from the "ecological subsistence minimum"

In this context, however, there is another legal aspect that was recognised (albeit too restrictively) by the Federal Constitutional Court in the climate decision[109] , but was not developed further: Via the ecological minimum subsistence level of the individual human being, which is anchored in human dignity, the planetary boundaries with their tipping points also convey an absolute legal limit to every political consideration. This, in conjunction with Article 20a of the Basic Law, is the link between the precautionary principle in climate

[102] BVerfGE 157, 30, paras. 19-21, 120 with 158 ff., 216 ff.
[103] BVerfGE 157, 30, para. 256 ff.
[104] *Kment*, NVwZ 2020, 1537 (1540), generally *Calliess*, Rechtsstaat und Umweltstaat, 2001, pp. 24 ff. and 344 ff.
[105] Instructive on this point *Cremer*, ZUR 2019, 278 ff; *Franzius*, ZUR 2017, 515 ff.
[106] BVerfGE 157, 30, para. 200 ff.
[107] Cf. after all BVerfGE 157, 30, marginal no. 139 ff.
[108] On this *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 181 ff. with 125 ff.
[109] Cf. BVerfGE 157, 30, marginal no. 113 ff.; critical of its approach *Calliess*, in: Herzog/Dürig/Scholz (eds.), GG-Kommentar, Art. 20a GG, marginal no. 185 ff.

protection and the intertemporal rights of freedom according to the BVerfG's climate decision.[110]

If, when the tipping points are exceeded, irreversible environmental damage threatens to result in a kind of "devastation scenario", then, from a legal perspective, the constitutional right of every citizen to the ecological minimum subsistence level, which flows from human dignity, the basic right to life and health and the environmental state objective (Article 1 (1) in conjunction with Article 2 (2) of the Basic Law and Article 20a of the Basic Law), is violated.

However, taking into account the orientation of Article 20a of the Basic Law towards future generations and thus the principle of sustainability including the precautionary principle, the ecological subsistence level is not only affected when these minimum levels are no longer guaranteed but - since irreversible environmental damage is at stake - already when extreme ecological hardship in the form of the aforementioned "devastation scenario" is possible. In this respect, the planetary boundaries together with their tipping points, i.e. in the field of climate protection the 1.5 to 2-degree target, formulate a rebuttable presumption. Accordingly, the claimants are not obliged to present and prove their case; rather, the opponents of the claim, i.e. the state institutions as addressees by the fundamental rights, must present and prove that with their protection concept, they have taken all necessary measures with regard to effectively steering away ("keeping their distance")[111] from the planetary boundaries and can thus safely guarantee the ecological minimum subsistence level.

Since the results of Earth system research show that measures are necessary in the light of planetary boundaries, but cannot specify them concretely for the community of states or individual states, the scientific state of affairs must be assessed normatively and politically in order to derive concrete conclusions.[112] For this reason alone, it is primarily up to the legislator to draw consequences from scientific findings on ecological limits. Since environmental protection aspects have to be weighed against conflicting constitutional concerns (economic

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[110] For more details, see *Calliess*, ZUR 2021, 323 (328 ff.).
[111] Thus already *Calliess*, ZUR 2019, 385; agreeing on the relevance of tipping points in the area of fundamental rights protection obligations also: *Meyer*, NJW 2020, 894 (897 f.) as well as *Buser*, DVBl. 2020, 1389 (1392); similarly on the determination of planetary boundaries or ecological load limits as a mix of knowledge-based and precautionary principle already *Köck*, ZUR 2017, 257 f.
[112] *Köck*, ZUR 2017, 257 ff; *Schlacke*, Grenzwert oder Politikziel? Dogmatik und Legitimität der 2°- Celsius-Leitplanke, in: Dilling/Markus (eds.): Ex Rerum Natura Ius?, 2014, p. 93 (96 f.).

freedom, principle of the welfare state), the state institutions, first and foremost the democratic legislature, necessarily have a political scope for shaping and weighing up the implementation of the protection concept.

Beyond the ecological minimum subsistence level defined in this way, the material target core of the state and Union target definition pursuant to Art. 20a GG and Art. 191, 11 TFEU, as well as the fundamental right to life and health (Art. 2 para. 2 GG or Art. 3 GrCh of the EU) set a framework for state legislation and the associated distribution of freedom via the aforementioned prohibition of inadequacy.[113] In this respect, the leeway of state institutions in concretising the concept of protection - for example via environmental quality targets[114] - is greater. Regarding this, they "only" have an optimisation mandate that is open to consideration[115] , but the more serious the foreseeable consequences of exceeding the planetary boundaries, the greater the weight to be attached to keeping a distance from the planetary boundaries in the political decision.[116]

All this has consequences for the scope of judicial review. Analogous to the decisions on the social subsistence minimum, in which the BVerfG does not give the legislature any guidelines on the exact amount of the entitlement, the ecological subsistence minimum is also about determining the minimum protection on the basis of the planetary boundaries. Analogous to the social subsistence minimum, the BVerfG can also control the procedure for determining the ecological subsistence minimum.[117] Specifically, the legislature must have sufficiently grasped and circumscribed the goal. Furthermore, it must have chosen a suitable calculation method within the scope of its discretion. At the same time, it must be ensured that the legislature has ascertained all the necessary facts and has kept within the bounds of what is justifiable in all calculation steps, as well as disclosing the methods and calculation steps used for constitutional court review.[118]

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[113] In detail *Calliess*, Rechtsstaat und Umweltstaat, 2001, pp. 451 ff. and 563 ff.; similarly *Brönneke*, Umweltverfassungsrecht, 1999, pp. 272 ff. and 471 ff.; *Sommermann*, Staatsziele und Staatszielbestimmungen, 1997, p. 439 ff.
[114] *Reese*, ZUR 2010, 345.
[115] *Brönneke*, ibid, p. 269 ff; *Sommermann*, ibid, p. 360 f.
[116] *Calliess*, ZUR 2019, 385; approvingly *Meyer*, NJW 2020, 894 (897 f.); *Buser*, DVBl. 2020, 1389 (1392).
[117] BVerfGE 125, 175, marginal no. 142.
[118] BVerfGE 125, 175, marginal no. 144; in principle, *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 125 ff.

Measured against these normative requirements, the fundamental right to an ecological minimum subsistence level in conjunction with Art. 20a GG results in a judicially controllable mandate to act. This mandate to act, in the course of which the institutions of Germany and the EU must visibly steer away from the planetary boundaries and avert a (further) overstepping of the ecological limits of the Earth by means of a suitable and effective as well as long-term, coherent and legally binding protection concept. Within this framework, the constitutional and European law requirement to maintain a certain distance acts as a concrete requirement to take action via the prohibition of inadequate measures if an unchanged continuation of environmental use exceeds (or, as in the case of climate protection, has already exceeded) the planetary load limits and thus endangers the stability of the Earth system as well as the ecological foundations of human life with a very high likelihood. As a result, the constitutionally recognised prohibition of under-protection thus requires a safety concept that is enacted by the legislature as an "absolute guard rail" of politics in the form of a binding guiding law - modelled on the benchmarks once suggested by the Federal Constitutional Court for financial constitutional law. [119]

For climate protection in particular, the Paris Climate Agreement and the European 2030 climate protection targets already provide a legal framework to which Germany and the EU are bound and which they must comply with as part of their climate protection policy.[120] In this context, the German Climate Protection Act (KSG)[121] represents a target-oriented approach. However, the law is still too weak, especially with regard to the monitoring of the implementation of the agreed targets[122] , as the independent "Expert Council for Climate Issues" established in § 11 and 12 of the KSG performs a mere emergency function, but not a real monitoring function[123] . Within the framework of the implementation of the "European Green Deal" on 29.7.2021, the EU has now also enacted a European climate protection law[124] , which considering its goals - not least in implementation of the requirements of the environmental

[119] For a detailed discussion, see *Calliess*, Rechtsstaat und Umweltstaat, 2001, pp. 125 ff. and 235 ff.
[120] *Saurer*, NVwZ 2017, 1574.
[121] *Scharlau et al.* NVwZ 2020, 1.
[122] For more details, see the special report of the German *Advisory Council on the Environment* (SRU), Demokratisch regieren in ökologischen Grenzen - Zur Legitimation von Umweltpolitik, June 2019, pp. 175-185 (available online).
[123] *Scharlau et al.* , NVwZ 2020, 1 (4 f.).
[124] Cf. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1119; on this, *Schlacke*, NVwZ 2022, 905 ff.

integration clause of Art. 11 TFEU – should lead to an institutional monitoring process beyond the modest approaches.[125]

V. Precautionary principle and "*climate engineering*": a risk/risk trade-off?

As explained above, in the risk society, new technologies in particular are often associated with uncertainty and insecurity with regard to the consequences of said technology. In this respect, climate protection poses additional challenges: There may be innovations and new technologies that help humanity to slow down or even stop climate change and thus prevent the planetary boundaries of the 1.5 to 2 degree target from being exceeded. Such innovations and technologies are discussed under the term "*climate engineering*" (CE). In this context, it is no longer "only" a question of balancing the risks of these technologies with economic freedoms, interests and opportunities, but at the same time also of including the ecological risks associated with not using these new technologies to combat climate change.

In this respect, the question arises first of all whether innovation and the precautionary principle represent a contradiction at all from a legal perspective or whether the two are not dogmatically intertwined (see 1.). Furthermore, the question arises whether there can be a risk/risk trade-off within the framework of the precautionary principle. Here, the main question is whether the precautionary principle might even require the development of CE technologies, because it is already foreseeable that mitigation policy is too ineffective from a global perspective and that the risks of excessive global warming are increasingly condensing into concrete damage for the (survival) of humans and the environment (see 2.).

1. Precautionary principle and freedom of innovation

The above explanations on the necessity of a multipolar proportionality test within the framework of the precautionary principle have already demonstrated that the precautionary principle and freedom of innovation are intertwined in the democratic constitutional state[126] and must be brought into balance with each other within the framework of a multipolar

[125] On the legal necessity *Calliess/Dross*, ZUR 2020, 456 (461 ff.); with regard to the EU's climate governance: *Schlacke/Knodt/Müller/Riegel*, integration 2021, 287 ff.
[126] In depth *Köck*, Die Entwicklung des Vorsorgeprinzips im Recht - ein Hemmnis für Innovationen zum nachhaltigen Wirtschaften?, in: Hansjürgens/Nordbeck (eds.), Chemikalienregulierung und Innovationen zum nachhaltigen Wirtschaften, 2005, p. 85 ff.

proportionality test. Specifically, there are calls for an "innovation principle", which is sometimes (mis)understood as a counter-principle to the precautionary principle.[127] Since scientific actors and companies can invoke the fundamental rights of Article 5 (3) of the Basic Law (freedom of science), Article 12 (1) of the Basic Law (freedom of occupation) and Article 14 (1) of the Basic Law (right to property) to protect their freedom to innovate along the chain of research, development and production, innovations are recognised and safeguarded as legally protected goods. At the same time, it is undisputed that the individual freedoms must be weighed against the concerns of the common good, in this case the requirements of environmental protection and the precautionary principle (cf. Article 20a of the Basic Law), and brought into a proportionate balance. From this point of view, there is no need for an independent innovation principle - at least from a legal point of view, the establishment of such a principle would not make any difference.[128]

Against this background, it must be examined - first and foremost by the legislator - in light of the principle of proportionality, which form of regulation adequately realises an environmental policy that is open to innovation but is simontaneously oriented towards precaution. Enabling alternative assessments within the framework of the proportionality test can create room for innovation. Building on this, experimental regulation, which for example allows a deviation from existing standards for certain activities and for a limited period of time, can best promote innovative approaches. As a result, regulation can also act as a driver of innovation, which results specifically from the interplay between competition with rules and practices of the existing field on the one hand and the influence of political targets and measures, technological innovation and market dynamics on the other.[129]

Innovations thus necessarily take place within a regulatory framework, within which the precautionary principle is also relevant. It should be emphasised that regulation primarily serves to realise important public welfare concerns; as a fundamental form of action of the EU, it thus represents not only a possibility for action, but also a mandate to act that follows from the constitution (e.g. Art. 20a of the Basic Law and fundamental rights obligations to protect).[130] This view, however, views regulation wrongly solely as an obstacle to innovation. From an

[127] On this debate *Calliess*, ZEuS 2021, 125 ff as well as *Appel*, in this volume.
[128] In depth *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 256 ff.
[129] *Calliess*, ZEuS 2021, 125 (134 ff.); but cf. also *Appel*, in this volume.
[130] In detail *Calliess*, Rechtsstaat und Umweltstaat, 2001, p. 104 ff. and p. 307 ff.

economic point of view alone, it is not enough to promote innovation processes; rather, it is precisely in the transitional phase of innovation from the niche to the broad market that flexible political-regulatory control by the state is required, which creates a stable framework providing companies with the necessary planning and investment security. This is mainly done through regulation, which can therefore also be a driver of innovation: Last but not least, regulation can stimulate and steer desired innovations in order to promote important public welfare goals such as environmental protection. It is no coincidence that such a perspective is also the basis of the European Green Deal.[131] In view of the planetary boundaries, the enormous challenges of present-day environmental policy in the area of climate protection in particular require not only reduction but also adaptation measures, in the context of which innovations in turn play a central role. If, as shown, the innovation principle must not be understood as a counter-principle to the precautionary principle from a legal perspective, it must be a matter of increasing openness to innovation in all phases of the policy cycle. Through this, the innovation principle can contribute to making state legislation open to innovation.

2. Climate engineering in the light of the precautionary principle

Following this, the question must now be answered as to whether there can be a risk/risk trade-off within the framework of the precautionary principle. In this respect, it is important to weigh the risks of the technology of *climate engineering* (CE) against the risks of not using this technology in the context of "keeping a distance" from planetary boundaries.

Efforts to date to mitigate climate change have focused primarily on strategies to reduce greenhouse gas emissions ("*mitigation*") and to cope with the effects of global warming by adapting to climate change ("*adaptation*").[132] Proposals to make CE measures fruitful for achieving the agreed climate goals were made in particular against the background that the options pursued so far have had too little effect because most industrialised countries are still struggling to achieve the necessary reduction targets.[133] Accordingly, CE is an approach that

[131] On this point, *Calliess/Dross*, ZUR 2020, 456 ff.
[132] The United Nations Framework Convention on Climate Change (UNFCCC) established the reduction of anthropogenic greenhouse gas emissions in 1992. At the 2010 Climate Change Conference in Cancún, the Parties confirmed for the first time "that adaptation must be treated with the same priority as emission reductions" and created the "Cancún Adaptation Framework"; for a more in-depth discussion, see *Markus/Schaller/Gawel/Korte*, NuR 2021, 90 ff.
[133] *Caviezel/Revermann*, Climate Engineering, Final Report on the TA Project "Geoengineering" Office of Technology Assessment at the German Bundestag (Working Report No. 159), 2014 p. 29f.

has found its way into the scientific and political debate as a third strategy in view of global warming and planetary boundaries.

a) "Climate engineering" as a response option to climate change

The term CE encompasses technologies that are intended to bring about a targeted, mostly large-scale manipulation of the planetary environment with the aim of counteracting anthropogenic climate change.[134] While the scientific debate generally and comprehensively refers to "negative emission technologies"[135] , the more concrete term CE is predominantly used. In the Anglo-American language, the terms "*geoengineering*", "*climate intervention"* or "climate *remediation"*[136] are also used synonymously. [137]The term CE emphasises that it is about the targeted technical influencing of the climate system and not about other interventions in the environment (such as reforestation measures[138]). [139]The partial term "*engineering*" also emphasises that such interventions are targeted .[140]

Within the sciences, the discussion on CE measures was largely triggered by a paper by Nobel laureate Paul J. Crutzen[141] , who brought the technical possibilities for influencing the climate into the scientific focus. [142]There is growing concern in the scientific community that climate-damaging emissions cannot be reduced rapidly enough and not as required , in order to minimise further risks of climate change.[143] Against this background, the use of CE has been (controversially) discussed for some time as a new strategic element of climate policy.[144] The

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[134] The Royal Society describes geoengineering as "*deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change* ", see *The Royal Society,* Geoengineering the climate , Science, governance and uncertainty, 2009, p. 1.
[135] Cf. *Markus/Schaller/Gawel/Korte,* NuR 2021, 90 (93 ff.); *Grunder/Fuss/Kalkuhl/Minx/Strefler/Merfort,* KlimR 2022, 18 ff.
[136] "Climate Remediation" could be translated as "climate rehabilitation" or "climate healing" n, cf. *Caviezel/Revermann,* Climate Engineering, 2014, p. 43.
137 *Caviezel/Revermann,* Climate Engineering, 2014, p. 43; *Priority Programme 1689 of the German Research Foundation,* Climate Engineering and our Climate Goals - an Overdue Debate, p. 24.; the term "*climate engineering*" is not without controversy. For reasons to reject this term and possible alternatives see *Caviezel/Revermann,* Climate Engineering, 2014, p. 43f.
[138] As, for example, with "negative emission technologies", cf. *Markus/Schaller/Gawel/Korte,* NuR 2021, 90 (93 ff).
[139] *Rickels et al,* Gezielte Eingriffe in das Klima?, Eine Bestandsaufnahme der Debatte zu Climate Engineering. Exploratory study for the Federal Ministry of Education and Research 2011, p. 9.
[140] *Rickels et al,* Targeted climate interventions?, 2011, p. 9.
[141] See *Crutzen/Albedo,* Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?, Climatic Change 77(3-4), 2006, pp. 211-220.
[142] *Caviezel/Revermann,* Climate Engineering, 2014, p. 31.
[143] *The Royal Society,* Geoengineering the climate, 2009, p. 1.
[144] *Rickels et al,* Targeted climate interventions?, 2011, p. 13.

CE debate culminated in projects for direct and deliberate intervention in the climate system being considered in the IPCC's 5th Assessment Report. [145]As long as it is uncertain that measures to reduce the CO2 concentration in the atmosphere are sufficient to prevent further heating of the earth, negative emission technologies can, may and must be discussed and considered as part of precautionary strategies.[146] Thus, interventions in the climate system could complement emission prevention measures . There is hope that CE projects could help to achieve the climate goals if previous measures are not sufficient to stop the increase in CO2 concentrations and thus avoid a climate catastrophe by "keeping a distance" from the planetary boundaries. [147]

CE technologies are accordingly seen as an (emergency) measure to counter climate change with a view to exceeding planetary boundaries.[148] Likewise, possible and potential tipping points in the climate system are cited as a reason for future CE deployment .[149] In the course of this, the realisation of CE measures has increasingly established itself in international climate policy as a potentially necessary option for action and a third strategic element in dealing with climate change. [150]

b) Opportunities and risks of CE technology

A number of different processes and technologies are discussed under the collective term CE, all of which aim to intervene in natural processes in order to modify the climate and ultimately slow down or even reverse climate change. [151] However, the use of CE measures is also fraught with great uncertainties and risks with regard to undesirable side effects for humans and the environment.[152] CE measures differ not only in terms of their technological approaches, but

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[145] See *IPCC*, Special Report: Global Warming of 1.5 °C, Summary, 2018.
[146] Art. 3 para. 3 of the United Nations Framework Convention on Climate Change is ambiguous in this respect. However, at the 2010 Climate Change Conference in Cancún, the Parties confirmed for the first time "that adaptation must be treated with the same priority as emission reductions" and created the "Cancún Adaptation Framework"; for a more in-depth discussion, see *Markus/Schaller/Gawel/Korte*, NuR 2021, 153 (esp. 155 ff.); also *Krüger*, Geoengineering und Völkerrecht, 2020, p. 409 f.; *Proelß*, JZ 2011, 495 (498); cf. also *Stoll*, in: Dilling/Markus, Ex Rerum Natura Ius? Sach- zwang und Problemwahrnehmung im Umweltrecht, 2014, p. 37; *Hartzell-Nichols*, A Climate of Risk - Precautionary Principles, Catastrophes, and Climate Change, 2017.
[147] *Priority Programme 1689 of the German Research Foundation*, Climate Engineering and our Climate Goals - an Overdue Debate, 2019, p. 7; *Caviezel/Revermann*, Climate Engineering, 2014, p. 31.
[148] *Rickels et al*, Targeted climate interventions?, 2011, p. 13.
[149] *Rickels et al*, Targeted climate interventions?, 2011, p. 41.
[150] In detail *Markus/Schaller/Gawel/Korte*, NuR 2021, 153 ff.
[151] "*Geoengineering proposals aim to intervene in the climate system by deliberately modifying the Earth's energy balance to reduce increases of temperature and eventually stabilise temperature at a lower level than would otherwise be attained* ", *The Royal Society*, Geoengineering the climate, 2009, p. 1.
[152] *Caviezel/Revermann*, Climate Engineering, 2014, p. 31.

also with regard to their development and research stage. While some of the proposals already seem technically mature, others are still mere concept studies .[153] Furthermore, CE technologies can also be categorised according to their impact character. This describes the spatial extent and the character of the potential side effects and consequences of a CE deployment for the climate, the environment and society. One can distinguish between local and global CE technologies. While the application of local CE technologies is spatially limited and their consequences are restricted to the area of application (e.g. CCS measures and whitening of settlement structures), global CE technologies have large-scale dimensions with regard to their application and potential environmental consequences (e.g. aerosol injection and ocean fertilisation).[154] Ultimately, the CE concept covers various proposals that differ greatly in their technical characteristics, mechanisms of action and possible (ecological) consequences as well as risks. In this respect, it is important to distinguish between two CE technology approaches on the basis of which the proposed CE measures can be divided into two categories e [155]

aa) Opportunities and risks of carbon dioxide removal technologies

The first are measures that reduce atmospheric greenhouse gas concentrations. These are generally referred to as carbon dioxide removal (CDR) technologies. They include ocean-based CDR measures such as ocean fertilisation and artificial upwelling, as well as land-based CDR measures such as direct air capture processes, BECCS, etc.[156]

Proposals with a CDR approach include measures to remove carbon dioxide from the atmosphere. CDR technologies consequently address the root cause of man-made climate change . They thus have a "causal" effect.[157] Basically, CDR concepts aim to remove carbon dioxide from the atmosphere through biological, chemical or physical processes, mostly analogous to natural CO2 sequestration .[158] This is intended to stop the accumulation of CO2 and even lower the CO2 concentration. The latter is achieved when more CO2 is removed from the atmosphere overall than is added. Accordingly, CDR measures are also referred to as

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[153] *Caviezel/Revermann,* Climate Engineering, 2014, p. 51.
[154] *Caviezel/Revermann,* Climate Engineering, 2014, p. 111.
[155] *Caviezel/Revermann,* Climate Engineering, 2014, p. 41; See for the dichotomy *The Royal Society,* Geoengineering the climate, 2009, p. 1.
[156] Cf. the overview in *Grunder/Fuss/Kalkuhl/Minx/Strefler/Merfort*, KlimR 2022, 18 ff.; *Markus/Schaller/Gawel/Korte*, NuR 2021, 90 (93 ff.).
[157] *Caviezel/Revermann,* Climate Engineering, 2014, p. 42.
[158] *Caviezel/Revermann,* Climate Engineering, 2014, p. 51; *Rickels et al.*, Gezielte Eingriffe in das Klima?, 2011, p. 41.

"*negative* emission technologies".[159] This term has become particularly common in connection with the Paris Climate Agreement. Accordingly, CDR measures in particular have the potential to act as a complement to existing emission reduction measures . However, apart from their opportunities as outlined above, various CDR measures also entail risks in the form of potential side effects and negative environmental impacts.[160]

In view of the fact that CDR measures aim to reduce the concentration of carbon dioxide in the atmosphere, there is a debate as to whether CDR measures should be included in the CE concept at all or, whether they should rather be regarded as part of mitigation[161] in accordance with the definition of the Intergovernmental Panel on Climate Change.[162] There is much to suggest that CDR measures also fall within the scope of CE, as they, in contrast to mitigation measures, only begin after CO2 has been released into the atmosphere .[163]

bb) Opportunities and risks of radiation management technologies

On the other hand, CE also covers methods that have a "symptomatic" effect. Approaches of so-called radiation management (RM technologies) aim to change the global radiation balance by such measures specifically intervening in the Earth's radiation budget. [164]Among the existing RM proposals, a distinction is made as to whether the measures influence short-wave solar radiation or long-wave thermal radiation . [165]

Technologies discussed under the RM approach (e.g. aerosol injection, cloud modification, light guidance in space) aim to modify the climate by intervening in the Earth's radiation budget

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[159] See, for example, Priority Programme 1689 of the German Research Foundation, Climate Engineering and our Climate Goals - an Overdue Debate, 2019, p. 24; also *Markus/Schaller/Gawel/Korte*, NuR 2021, 90 ff. and 153 ff.
[160] *Markus/Schaller/Gawel/Korte*, NuR 2021, 90 (96 ff.); largely omitted in *Grunder/Fuss/Kalkuhl/Minx/Strefler/Merfort*, KlimR 2022, 18 ff;
[161] The Intergovernmental Panel on Climate Change defines *mitigation* as "a human intervention to reduce emissions or enhance the sink of greenhouse gases ", *IPCC,* 2018, Annex I: Glossary [Matthews, J.B.R. (ed.)]. In: 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.
[162] *Priority Programme 1689 of the German Research Foundation,* Climate Engineering and our Climate Goals - an Overdue Debate, 2019, p. 24; *Caviezel/Revermann,* Climate Engineering, 2014, p. 42.; On the categorisation of CDR measures or NETs as mitigation measures n, see also *Markus et al.* 2021, 90 (97 f.).
[163] Cf. *Caviezel/Revermann,* Climate Engineering, 2014, p. 42.
[164] *Caviezel/Revermann,* Climate Engineering, 2014, p. 41; *Edenhofer/Jakob*, Klimapolitik, 2nd ed.
[165] *Rickels et al,* Gezielte Eingriffe in das Klima?, 2011, p. 41; *Edenhofer/Jakob*, Klimapolitik, 2nd ed.

by means of large-scale technical interventions.[166] RM technologies influence either short-wave solar radiation (*Solar Radiation Management*, SRM) or long-wave thermal radiation (*Thermal Radiation Management*, TRM).[167] Basically, the aim is to reduce the average global temperature without reducing greenhouse gases in the atmosphere.[168] Thus, the aim of these technologies is to bring about an RM-induced negative radiative forcing in order to compensate for the positive, anthropogenic radiative forcing.[169] Accordingly, RM technologies do not address the cause of climate change per se, but merely combat the symptom of global warming by aiming to reduce the global mean temperature .[170]

In purely theoretical terms, the potential of global RM technologies (e.g. aerosol injection, cloud modification, light guidance in space) is predominantly estimated to be very high.[171] Computer simulations show that the cooling effect of RM measures on the mean temperature could unfold very quickly compared to CDR measures or emission reduction measures , and they would also be associated with only low deployment costs.[172] In theory, RM measures would therefore have the potential to cool the Earth significantly within a short period of time.[173] However, their technically realisable potential is still uncertain. Accordingly, there are still high model uncertainties and their functioning has not yet been tested experimentally.[174] Local RM technologies (e.g. brightening the Earth's surface), on the other hand, are considered to have low potential. They would not have a decisive influence on the climate.[175] In this respect, it should at most be considered whether local experiments could be suitable for gaining experience in order to test an application on a large scale. A precautionary strategy here could be based on the step-by-step principle known from §§ 3 No. 3 and 36 of the Genetic Engineering Act.[176]

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[166] *Priority Programme 1689 of the German Research Foundation,* Climate Engineering and our ; *Edenhofer/Jakob*, Klimapolitik, 2nd ed. 2019, 64 ff. (on Solar Radiation Management).Climate
[167] *Rickels et al,* Targeted climate interventions?, 2011, p. 41; *The Royal Society*, Geoengineering the climate, 2009, p. 1.
[168] *Caviezel/Revermann,* Climate Engineering, 2014, p. 41.
[169] *Caviezel/Revermann,* Climate Engineering, 2014, p. 84.
[170] *Caviezel/Revermann,* Climate Engineering, 2014, p. 41f.
[171] *Caviezel/Revermann,* Climate Engineering, 2014, p. 113.
[172] *Caviezel/Revermann,* Climate Engineering, 2014, pp. 42, 93.
[173] *Rickels et al,* Targeted climate interventions?, 2011, p. 42.
[174] *Caviezel/Revermann,* Climate Engineering, 2014, p. 113.
[175] *Caviezel/Revermann,* Climate Engineering, 2014, p. 114.
[176] Thus *Köck* (in this volume); on the concretisation of the precautionary principle in genetic engineering law in this respect *Appel*, Gentechnikrecht, in: Ehlers/Fehling/Pünder (eds.), Besonderes Verwaltungsrecht, vol. 2, 4th ed. 2020, § 51, marginal no. 27; in detail *Appel*, NuR 1996, 227 ff; *Calliess/Korte*, DÖV 2006, 10 ff.

At the same time, there are fears of major risks and side effects with regard to humans and the environment. Regardless of the RM technology in question, there are a number of possible side effects and risks that could arise from interventions in the global radiation balance.[177] Many are due to the fact that RM technologies aim to reduce the medium temperature and not the emission of greenhouse gases. This symptom control approach has some general consequences.[178] First, RM measures refer to the so-called termination problem.[179] This means that in the event of a sudden termination of RM measures, a rapid and potentially catastrophic rise in temperature is feared.[180] This temperature rise could be much faster than it would have been without RM interventions. As a result, there would be a greater threat to the adaptive capacity of biodiversity than can already be observed at present. Furthermore, the use of RM technologies would result in a new climate, which could be very different in terms of climate variables compared to a climate without RM intervention.[181] RM technologies could also cause changes in global wind and water circulation. This in turn would have an impact on various climate variables, such as precipitation intensity and distribution, wind patterns and the overall weather pattern.[182] Against the background that RM interventions cause a reduction in global medium temperature instead of CO2 reduction, GHG concentrations remain unchanged in the atmosphere or continue to rise. This has consequences for ecosystems and the global carbon cycle.[183]

c) Conclusions

In conclusion, the above explanations have shown that the spectrum of the CE methods presented is just as broad as that of their potential modes of action and side effects. However, many of the CDR and RM measures illustrated are so far only purely theoretical considerations that are not yet mature enough to be used on an industrial scale. To have a significant impact on the climate, CE would have to be deloyed for a very long period of time.[184] Large-scale deployment, in turn, entails certain risks whose consequences can hardly be assessed at

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[177] *Markus/Schaller/Gawel/Korte*, NuR 2021, 90 (96 ff.).
[178] *Caviezel/Revermann,* Climate Engineering, 2014, p. 86.
[179] *Caviezel/Revermann,* Climate Engineering, 2014, 93 f; *Priority Programme 1689 of the German Research Foundation,* Climate Engineering and our Climate Goals - an Overdue Debate, 2019, p. 40f.
[180] See *Brovkin et. al.* Geoengineering climate by stratospheric sulphur injections: Earth system vulnerability to technological failure, Climatic Change 92, 243-259, 2009; See *Ross/Matthews*, Climate engineering and the risk of rapid climate change, Environmental Research Letters, p. 45103, 2009.
[181] *Caviezel/Revermann,* Climate Engineering, 2014, p. 86f.
[182] *Caviezel/Revermann,* Climate Engineering, 2014, p. 86f.
[183] *Caviezel/Revermann,* Climate Engineering, 2014, p. 92.
[184] *Priority Programme 1689 of the German Research Foundation,* Climate engineering and our climate goals - an overdue debate, 2019, p. 23.

present.[185] Overall, the state of scientific knowledge, especially with regard to the ecological effects, is therefore still very limited.[186] In addition, side effects could be transboundary. In many cases, there are scientific, legal, ethical or political concerns about the use of the methods.[187]

Following the above, a distinction should be made between RM technologies and CDR measures with regard to the precautionary principle. While RM technologies are seen as having great (albeit still largely theoretical) potential to slow climate change and respect planetary boundaries[188], CDR measures are not seen as having a rapid impact on global temperatures, so they should be considered as complementary to existing emission reduction measures.[189] However, it is crucially important that RM technology - as outlined above - is linked to risks (in the sense of possible dangers) whose damage potential for the environment and climate is immense and partly irreversible with regard to the human subsistence level. Since the described risks of measures within the framework of RM technology are therefore already disproportionately high in general when weighed against the risks of not using this technology, there can generally be no risk/risk trade-off in this respect in the light of the requirements of the precautionary principle outlined above.

According to the above, a different approach can be assumed for CDR measures. Since the risks they pose are associated with a possible damage potential for the environment and climate that is relatively more limited, a differentiated application appears possible with regard to a risk/risk trade-off in light of the precautionary principle. In addition, CDR measures - unlike RM methods - also address the causes of climate change.[190] Against this background, each individual CDR measure must be examined with regard to the requirements of the precautionary principle. In this respect, the rebuttable presumption of danger and - within the framework of the proportionality test - the alternatives test are of decisive importance. In the course of this, pilot projects in the context of a multi-pole proportionality test are a milder means than bans on

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[185] *Priority Programme 1689 of the German Research Foundation,* Climate engineering and our climate goals - an overdue debate, 2019, p. 41.
[186] *Caviezel/Revermann,* Climate Engineering, 2014, p. 114; *Markus/Schaller/Gawel/Korte,* NuR 2021, 90 (96 ff.
[187] *Priority Programme 1689 of the German Research Foundation*, Climate engineering and our climate goals - an overdue debate, 2019, p. 23; *Markus/Schaller/Gawel/Korte*, NuR 2021, 90 (96 ff.).
[188] *Caviezel/Revermann,* Climate Engineering, 2014, p. 113.
[189] *Caviezel/Revermann,* Climate Engineering, 2014, p. 42.
[190] *Priority Programme 1689 of the German Research Foundation,* Climate engineering and our climate goals - an overdue debate, 2019, p. 25.

CDR technology.[191] This is because they are aimed at gaining further scientific knowledge about the possible damage of CDR measures, which enables a differentiated risk/risk trade-off in weighing up opportunities and risks.

This option was convincingly spelled out in 2009 by the German Advisory Council on the Environment (SRU), which advises the federal government, using the example of underground storage of CO2 (CCS).[192] The SRU did take a critical view of the draft law on regulating the capture, transport and permanent storage of carbon dioxide, which was passed by the federal cabinet at the time, with regard to opportunities and risks, since "many technical and ecological questions in connection with CCS are still unresolved" and "competition for the use of underground spaces" as storage facilities was considered likely. However, in order to not let the opportunities of CCS lie fallow with regard to climate protection, the SRU favoured a research law that would enable the testing of CCS in pilot projects.[193]

VI. Summary

1. In climate protection, but also with regard to other areas of environmental policy such as biodiversity, the concept of planetary boundaries, determined within the framework of Earth system sciences, has been shaping the discussion for several years. The international climate protection goals agreed in the Paris Agreement, which call for limiting man-made global warming to well below 2°C compared to pre-industrial levels, but preferably to 1.5°C, represent a concrete planetary boundary.

2. There is a gap between scientific knowledge and the political commitment to planetary boundaries as "guard rails" for sustainable action on the one hand, and the level of ambition of the state authorities strategies and programmes adopted in this respect on the other. This gap deepens as soon as it comes to binding implementation in law and their enforcement.

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[191] *Markus/Schaller/Gawel/Korte*, NuR 2021, 153 (158) aptly state: "There are many arguments in favour of further scientific research into the functioning and extraction potential of NETs. Against this background, it would now be necessary to investigate individual, promising measures with greater depth. Only in this way can rational weighing-up decisions ultimately be made with regard to the conditions of their possible use."

[192] In this respect, however, the author of this contribution, who was a legal member of the SRU from 2008-2020 and in this capacity contributed to the opinion, may be biased.

[193] *German Advisory Council on the Environment* (SRU), Abscheidung, Transport und Speicherung von Kohlendioxid: Der Gesetzentwurf der Bundesregierung im Kontext der Energiedebatte Opinion of 06.05.2009 (available online at: https://www.umweltrat.de/SharedDocs/Downloads/DE/04_Stellungnahmen/2008_2012/2009_05_AS_13_Stellung_Abscheidung_Transport_und_Speicherung_von_Kohlendioxid.pdf?__blob=publicationFile&v=2).

3. A decisive reason for this gap in political action is that the concept of planetary boundaries cannot present any "scientific evidence" with regard to the thresholds and tipping points, but must operate with the concepts of scientific uncertainty and insecurity typical of the risk society. At this point, the situation determined by earth system science must be normatively and politically evaluated. This is an important starting point for linking the planetary boundaries with the precautionary principle.

4. The legal interface to planetary boundaries is first and foremost the state objective of environmental protection in Article 20a of the Basic Law, including the precautionary principle immanent to this norm. This is because both risk precaution and resource precaution aim to avoid critical burdens and to keep a distance from the tipping points identified by Earth system science, so that serious and irreparable damage to humans and the environment is avoided. With regard to scientific uncertainty and insecurity, the precautionary principle implies a reversal of the burden of proof in the form of a science-based rebuttable presumption of danger.

5. The legal concept of climate protection, which state authorities according to Article 20a of the Basic Law are supposed to deliver, must be balanced against fundamental rights as well as legal principles united under the umbrella of the rule of law (e.g. legal stability and certainty). It is therefore no coincidence that the principle of proportionality is unanimously described in practice and literature as a limit of the precautionary principle. In the triangle between the environmental state objective of Article 20a of the Basic Law, state authorities duties to respect and protect fundamental rights, a multipolar constitutional law relationship arises, in the framework of which a multipolar proportionality test forms the yardstick for the precautionary measure with regard to the protection concept.

6. Through the ecological minimum subsistence level of the individual human being, which is anchored in human dignity, the planetary boundaries with their tipping points also convey an absolute legal limit to political discretion. In conjunction with Article 20a of the Basic Law and the precautionary principle, this formulates a legal triad with the intertemporal preservation of freedom according to the climate decision of the BVerfG. Within this framework, the planetary boundaries together with their tipping points, i.e. in the area of climate protection the 1.5 to 2 degree target, formulate a rebuttable presumption. In the course of this, the claimants are not obliged to present and prove their case, rather the state institutions as

addressees of fundamental rights must present and prove that within their protection concept they have taken all necessary measures with regard to an effective steering away from planetary boundaries.

7. Technologies to combat climate change, such as climate engineering (CE), are - like all new technologies - associated with uncertainty and insecurity with regard to the consequences of the technology or unintended side effects. Precisely in this respect, risk prevention (see 5.) plays a central role. In CE, however, it is no longer "only" a question of balancing environmental precaution with economic freedoms, but at the same time of including interests of climate protection. In this context, the main question is whether there can be a risk/risk trade-off in preventing risks.

8. In this respect the spectrum of envisaged CE methods, their potential modes of action and side effects is very broad. With regard to the precautionary principle, a distinction should be made between RM technologies and CDR measures. Even if RM technologies are considered to have a greater (albeit still largely theoretical) potential than CDR measures in terms of slowing down climate change and respecting planetary boundaries, they are associated with risks whose potential damage to the environment and climate is immense and in part irreversible in terms of human subsistence. In light of the precautionary principle outlined above, there can be no risk/risk trade-off.

9. According to the above explanations, a different approach can be assumed for CDR measures. Since the risks they pose to the environment and climate are more limited, a differentiated approach appears possible for a risk/risk trade-off in accordance with the precautionary principle described above: In this respect, the rebuttable presumption of danger and - within the framework of the proportionality assessment - the alternative assessment are of scale-setting importance. In the context of a multipolar proportionality test, pilot projects in particular are a milder means than precautionary bans on CDR technology.