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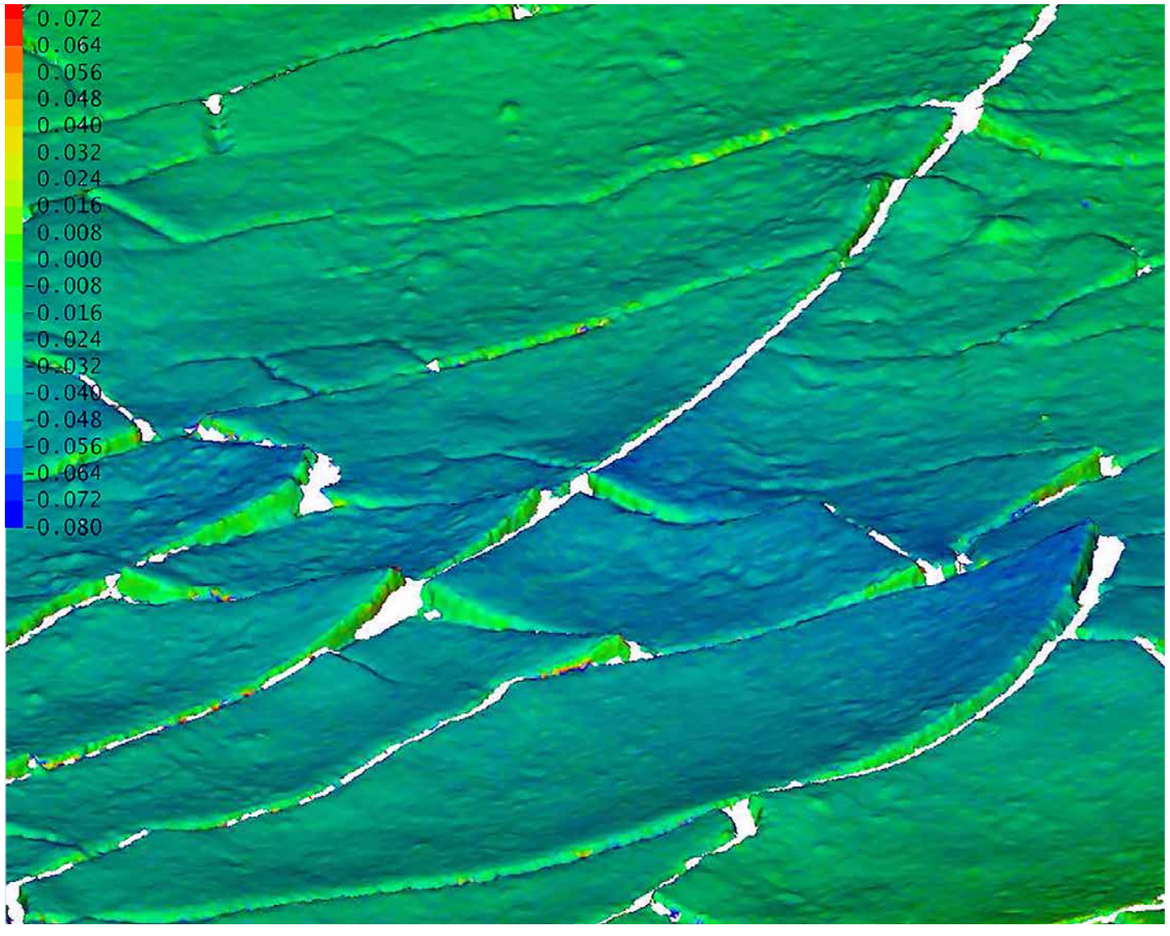
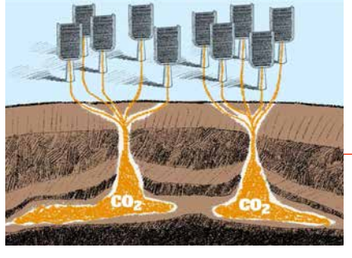


Micro Damage: Travelling Artworks | **International Cooperation:** The War as a Turning Point for Science and the Humanities | **Law in the Pandemic Crisis:** The State is Expected to Provide an All-round Carefree Package | **European Asylum Law:** In-between Spaces | **Climate Engineering:** Let's Save the Climate! But How?

Cover: AG Krekel

Damage on the coloured paint layer of a painting. Art technologists and conservators rely on a technique to compare high-resolution 3D models and precisely detect damage caused by transport, for example.



Katja Becker

The War as a Turning Point for Science and the Humanities

After the Russian attack on Ukraine: the suspension of institutional research cooperation is the logical response to the breakdown of all the values on which science and the humanities are based and indeed civilisation itself. At the same time, it is important to provide help for researchers who have fled from both Ukraine and Russia – not least in preparation for an aftermath of war that is not yet foreseeable.

We too were unable to imagine something like this would happen – a cruel reality that has now been with us for nearly two months: war in the midst of Europe. Thousands are dying, thousands more have taken flight. Tanks and rockets are devastating entire cities and regions, place names such as Mariupol and Bucha have become synonyms for horrific atrocities.

This war, this utterly unjustified attack by Russia on Ukraine, is – in the words of the German Chancellor, quoted many times – a "turning point" for science and the humanities, too. And just like all areas of our society that science and the humanities influence in diverse ways and which in turn variously impact on scientific endeavour, this war forces us to respond. Our response consists of two elements: a fundamental attitude and concrete action.

Science and the humanities – the German research system – gave its answer both quickly and unequivocally: just one day after the Russian invasion of Ukraine, the Alliance of Science Organisations in Germany – in which the DFG has the role of the speaker this year – not only condemned the invasion in the strongest possible terms, it also assured all researchers who had been forced to leave their homes or suffer persecution that they could rely on its solidarity and assistance. It previously issued a general statement of action which the Alliance members subsequently put into practice themselves within a few days.

As the largest research funding organisation not only in Germany but in the whole of Europe, the DFG suspended all German-Russian research cooperation at the institutional level until further notice at the beginning of March. In this way, we are deliberately focusing on the projects that are co-financed on the Russian side by our institutional partner organisations, which in this case are state organisations – a crucial point in this connection. The project components on the German side will continue to be fully funded by the DFG. Funding proposals for new bilateral projects and renewal proposals for existing projects will no longer be accepted for the time being (see also the article on pp. 4–5).

In taking these steps, we are supporting the German government's resolute action in response to Russian aggression. And our actions form part of an international response through which policymakers and academics in numerous countries are declaring that this aggression must be countered using all peaceful means at our disposal.

We strongly believe that this response is not only consistent, it is the only possible option. After all, the Russian attack on Ukraine not only blatantly violates the territorial integrity of an independent and democratic state, it is also an assault on all fundamental values such as freedom, democracy and self-determination – values on which science and the humanities and international cooperation in research are based.

We must stand up for these ideals against authoritarian regimes in times of peace, but even more so in the event of conflict. The war of aggression on Ukraine demonstrates to what extent these values are under

Illustration: DFG / Ausserhofer

threat – not for the first time, though especially forcefully in this case. This is why taking action here is also about defending what we believe in. And the more clearly we position ourselves, the greater the impact we will be able to achieve and the more clearly our protest will be perceived by those against whom it is directed. It is precisely in symbolism that the power of our actions lies.

At the same time, we are acutely aware of the implications of our actions and regret their consequences from the point of view of scholarly endeavour. Restrictions such as the ones we are now imposing touch the very core and self-image of science and the humanities and their organisations and institutions, as well as the many thousands of academics involved in them. They all see themselves as bridge builders, especially in times of crisis, and have often had a positive and productive impact in the past.

And in very concrete terms: many of the joint projects we have funded that have now been suspended address global challenges such as climate change and species extinction, for which cross-border research cooperation is indispensable, especially in our multidimensional world. Even for Germany alone, it will not be possible to continue to pursue some of the work in the same way as before, though project leaders are free to continue the German parts of projects, even without Russian participation. But for the Russians, it is already foreseeable that a lack of bilateral or multilateral cooperation will lead to a weakening of Russia as a research location in the medium term: this in turn is likely to have an impact on scientific progress, international competitiveness and social prosperity in Russia.

Yet we cannot emphasise often enough: it was and is Russian aggression that has caused the bridges of science and the humanities, too, to be shaken in their very foundations. And it is the state institutions of Russian academia that are supporting this aggression –

as demonstrated by a particularly shocking joint appeal signed by more than 200 university directors. Even if we can imagine that not all of them signed voluntarily, cooperation with such partners is simply not conceivable or justifiable for the time being.

By specifically taking our action at the institutional level, we also want to consciously distinguish between the state and civil society, as we continue to maintain the numerous individual contacts between German and Russian researchers and the channels for dialogue that these provide. Only in this way will it be possible to revive stable, longstanding academic relations in Russian society after a hopefully early end to war and violence.

Resolute action is therefore the order of the day on the one hand. On the other hand, help is required. The already dramatic exodus from Ukraine – probably the largest movement of refugees since the end of the Second World War – is also an exodus of academics, with many highly qualified researchers leaving their homeland and coming to Germany in the course of these days and weeks, most of them risking their lives to do so.

We want to offer them the greatest possible support as part of our aid initiative for refugee researchers. In this connection, it has turned out to be a fortunate coincidence that, while the initiative has existed since 2015, we expanded it just at the end of last year by opening up the Walter Benjamin Programme. For example, it is no longer only German heads of DFG-funded projects who can apply for additional funding to involve refugee Ukrainian researchers: the latter can now also submit a proposal for their own research project so as to be able to continue their scholarly work in the German research system. For both variants we expect to receive a very significant number of funding proposals, the first of which are already starting to come in. In order to be able to provide immediate aid here, the aim is to process the proposals more quickly and in a more streamlined fashion.

But we are offering the same help to researchers from Russia who have turned against the war with admirable courage in their home country: the only way they can now escape reprisals may be by fleeing. They, too, are to be able to continue their work through temporary integration in the German research system – and they might one day contribute as "ambassadors" to thawing frozen relations when it comes to initiating new German-Russian collaborations.

Despite all the help needed at this time, we must look to the future, too. For the DFG, there is no question that it will remain committed to science and the humanities in Ukraine in the long term. What form this will take in detail is, of course, not yet foreseeable and depends on further political developments.

If there is a political system in Ukraine after the end of the war that guarantees freedom, including academic freedom, it will be necessary – and in the interests of science and the humanities in Germany – to support reconstruction and recovery. This could then be handled in such a way that the DFG finances the Ukrainian share of bilateral research projects. But if the current Russian demand for a de facto annexation of Ukraine becomes a reality, science and the humanities in Germany will have to reckon with an even greater migration movement. Neither scenario will be manageable without additional funds, and the DFG has already requested the German government to increase resources in this area.

Here, as with all other issues arising from this war, the DFG relies on close and trusting cooperation between science and policymakers, and intends to contribute to the best of its ability. This also applies to the discussion of overarching implications such as the impact on science diplomacy, value-oriented foreign science policy and science policy consultation. These issues will also have to be revisited in the light of recent events – developments we would previously have discussed at best theoretically as "crossing a red line". Here again, this war is a turning point.

Professor Dr. Katja Becker
is the President of the DFG.

Implement Suspensions, Keep Channels Open, Provide Help

DFG measures after the Russian attack on Ukraine – an overview

A logical step – the cessation of all close collaboration: at the time the Russian tanks rolled into Ukraine at the end of February, the DFG, together with its Russian state partner organisations – the Russian Science Foundation (RSF) and the Russian Foundation for Basis Research (RFBR) – were funding a total of 183 joint German-Russian projects across virtually all subject areas and with the participation of numerous universities and research institutions in both countries.

Suspension of these joint projects at the institutional level is at the core of the measures that the DFG decided to adopt as early as 1 March in response to the Russian attack on Ukraine. In concrete terms, this means that until further notice, no joint research work is to take place as part of these projects and in particular, no data, samples, equipment or other scientific material is to be exchanged. The project components on the German side can still be continued and will receive approved funding for this purpose; whether and to what extent continuation is possible without the suspended elements is up to those responsible for the project in Germany.

For the time being, however, participating researchers are not to travel to Russia, nor can there be any joint workshops, conferences or academic events involving Russian researchers. Ongoing guest stays do not have to be terminated, but new ones should not be started or planned.

Not only have existing collaborations been suspended, the DFG will now not accept proposals for new German-Russian funding projects for the time being, just as it will not accept renewal proposals for ongoing bilateral projects. Proposals that have already been submitted, such as those under the joint call for proposals with the RSF, are suspended until further notice and will not be processed further. For this reason, no decision can be taken regarding renewal proposals for ongoing projects. Bridge funding is not possible in such cases either.

Researchers who are currently applying for a fellowship abroad for Ukraine or Russia may alter their applications and specify a different destination country. Scholarships that have already been approved are not to be taken up. Current scholarships can be converted into domestic scholarships or positions; here, too, there is the option of moving to another country.

So while cooperation at the institutional level is suspended, the many existing contacts at the individual level between German and Russian researchers are to be kept open. At more or less the same time as it adopted the measures affecting German-Russian cooperation projects, however, the DFG also initiated the first aid measures to help researchers from Ukraine – as well as from Russia – who have had to leave their home countries as a result of the Russian attack or for fear of reprisals. Since the beginning of March, they have been able to receive support under the DFG's aid initiative for refugee researchers: while this initiative has been in place since 2015, it was significantly expanded just recently – independently of the events in Ukraine – with the opening of the DFG's Walter Benjamin Programme.

In this way, refugee doctoral graduates are now also able to continue their academic work by pursuing their own project within the German research system. The first applications for aid have already been received at the Head Office. **fine**

www.dfg.de/en/service/press/press_releases/2022/press_release_no_01

Rembert Unterstell

Illustration: BMI

„The State is Expected to Provide an All-round Carefree Package“

Law in the pandemic crisis: the dilemma of the Infection Protection Act, a constitutional reading of vaccine mandates and the government's management of civil liberties on the way to a "preventive state". In conversation with Frankfurt constitutional lawyer Uwe Volkmann, a member of the DFG's Pandemic Commission

„forschung“: *Professor Volkmann, we are conducting this interview in mid-March. The current pandemic restrictions are to be eased extensively or eliminated altogether in the near future. Yet infection rates are high and we can see that neither the pandemic nor pandemic control are over yet. Is it possible to resolve this underlying dilemma that faces the new Infection Protection Act?*

Volkmann: The underlying dilemma will always be there, and there are two points of view to consider. Firstly, the significance of infection rates has changed – they mean something different today than they did a year or two ago. Secondly, vaccination is a reasonable option for everyone to at least protect themselves from becoming severely ill. There are other ways to protect oneself effectively, too, such as by wearing an FFP2 mask. This shifts the weight of responsibility between what the state takes on and what is shifted back onto the individual. The option to get vaccinated has been a constitutional tipping point here, too.

The new Infection Protection Act focuses on "basic measures" and a "hotspot strategy". If the central legal and explanatory justification for the pandemic response – averting overburdening of clinics and the healthcare system – no longer applies, do the restrictions have to be eased?

Essentially I would say yes. However, one prerequisite here is that there is an understanding of what the purpose of the measures is. Ultimately, this has never been clarified at the political level, and it has always remained unresolved in the Infection Protection Act: is the aim to prevent every single infection or just ensure the healthcare system is not overburdened? Both objectives are assigned equal priority in the Infection Protection Act, but the balance between the two remains in limbo. The political protagonists are essentially free to set the objective. But if the aim is to continue to prevent the overburdening of the healthcare system, then this necessarily means that if the relevant risk no longer applies, the measures must be eased or suspended.

Beyond the ubiquitous overload narrative, the justification provided for the restrictive measures is that of protecting life and health. Does this apply equally when a pandemic emergency becomes an endemic situation?

First and foremost, we have to look at how the protection of life and health in the constitution relates to other constitutional assets. Life and health are very valuable legal assets, but they cannot claim absolute priority over other legal interests: the means used to protect them must be weighed up against the impairment of these other legal interests. The only constitutional principle that can claim primacy over all others is the protection of human dignity – this is the highest value underlying the constitution.

Since the start of the pandemic, policymakers have embraced the principle of proportionality. Many people still recall Merkel's words that all protective measures must be "effective, necessary and appropriate". But has proportionality actually shown itself to be a regulating force?

Here again, the answer seems to me to have two sides: the constitutional argument is certainly stronger in Germany than in other countries. This is probably one of the reasons why we've never had excessive measures here in Germany – I'm thinking of the curfews in France where people were limited to an area of 900 metres around their own home. On the other hand, it has been shown that proportionality is difficult to implement in a situation where there is a large-scale and complex threat like a pandemic.

How do you rate the much-debated general vaccine mandate which is now to be launched in the Bundestag after the so-called "institutionally based" vaccine mandate?

I consider a general vaccine mandate to be constitutionally justifiable based on the key question of how serious you consider the encroachment on physical integrity that such a vaccination involves. Objectively speaking, I don't believe it's too serious. At the same time, however, the goal of this vaccine mandate must be determined: what does it actually aim to achieve? If the goal is societal resilience that enables a return to normal life for everyone, there are good constitutional arguments for compulsory vaccination. But then there is an important logical step to take: compulsory vaccination, yes – but then the other measures have to be suspended.

The pandemic regime of recent months has involved special rights for the vaccinated and those who have recovered from the illness, including admission to certain activities and places where evidence of vaccination, tests etc. is required. Do you consider these special rights to be constitutional?

The principle of equality before the law applies: equal things are to be treated equally, but unequal things are to be treated unequally, too. If vaccinated and recovered individuals pose less of a risk in terms of overburdening the healthcare system and also of transmitting infections, then it is not only constitutionally permis-

Professor Dr. jur. Uwe Volkmann …

… has held the Chair of Public Law and Philosophy of Law at the University of Frankfurt/Main since 2015. His research focuses on constitutional theory, questions of fundamental rights, democratic theory and party law. He has also advised various parliamentary groups in the Bundestag on issues of constitutional law in the fight against the pandemic; Volkmann has been a member of the DFG's Pandemic Commission since 2020.

www.jura.uni-frankfurt.de/53951249/zur_Person

sible, it is indeed imperative to put vaccinated people in a better position than unvaccinated people.

Where does collective responsibility end in the pandemic and where does individual responsibility begin?
Let me cite an old phrase of political liberalism: insofar as the state's mandate to protect health can only be fulfilled through a system of restrictions on liberty, this mandate to protect ends where it is reasonably possible for each individual to protect themselves. The problem is that in the course of the pandemic, the weighting between these two elements – collective responsibility and individual responsibility – has shifted. Increasingly, the state has been expected to provide an all-round carefree package.

In retrospect, would there have been alternatives to the state's pandemic policy?
Constitutionally speaking, there is a whole range of possible responses. The democratically decided pandemic policy pursued is one option under constitutional law, but it would also have been possible from the point of view of a principled protection of life and health to opt for a more liberal path, as Sweden has done for some time. One of the problems of fighting pandemics is that we have become accustomed to the constant management of individual freedoms by the state.

We will keep you posted about the impact the coronavirus pandemic has on the DFG's work and about all measures taken to date and in the future on our website www.dfg.de and via Twitter @dfg_public.

The state has restricted civil liberties with both a curative and preventive intent. When can a "preventive state" pose a threat to the rule of law?
Since the 1980s and 1990s, the state has been seen to think and act more preventively. But there is one problem with the preventive state: the number of theoretical sources of danger is always greater than the number of actual dangers. Risks can lurk everywhere – anything is possible at all times. Based on this logic of what might possibly happen, far-reaching state interventions can always be justified.

"Stop COVID-19" on the door of an intensive care unit. What will happen to the pandemic after many basic hygiene measures have been discontinued? Federal and regional pandemic management will continue to have to answer numerous legal questions.

Illustration: dpa/Robert Michael

Illustration: dpa/Sascha Steinach

Fundamental civil rights were repeatedly restricted in the course of the pandemic. Constitutional assets have a major role to play in the dispute over civil liberties.

Talking of what might possibly happen: is the impression deceptive that the modes and procedures of political crisis management have fundamentally changed?
Here you're referring to a fundamental problem of pandemic response. For the most part, the modes and procedures used have largely bypassed what is laid down in the constitution; after all, the constitution does not provide for a forum such as the Conference of State Premiers with the participation of the Chancellery – a constellation where for a long time all the major decisions were made. By the same token, the options offered by parliamentary procedure have been systematically passed over – and this is still true today. This is also why any consent regarding the intrinsic justification of the measures has failed to materialise.

In view of this deficit: which unresolved fundamental question of a constitutional nature would you see as most important today?
When one talks about the constitution, there is often a categorical juxtaposition of "constitutional" versus "unconstitutional". In fact, the constitutional argument is more complex than this: it is ultimately anchored in the contexts and circumstances of our lives. Constitutional assets always have some part to play in the dispute regarding political measures. In the constitution, we negotiate the self-image of our society – the principles that are to determine the way we live together. This self-image is susceptible to shifts that are reflected in changing interpretations of the constitution.

What does that mean in the context of the pandemic?
In this case, the fundamental shift concerns the relationship between individual responsibility and collective responsibility. In my view, people are too quick to call for the state and for the relevant restrictions to be imposed rather than involving civil society more and relying on individual responsibility.

What follows from this?
The result is that after two years of the pandemic, people are no longer asking themselves "What should I do?" but only "What am I allowed to do?" or, conversely, "What are they prohibiting again now?". You might say there has been a systematic devaluation of personal responsibility: this is the basic constitutional problem that we should perhaps reflect on here.

Thank you very much for the interview!

Interview: Dr. Rembert Unterstell,
Publishing Executive Editor of "german research".

Illustration: dpa / Inderlied / Kirchner-Media

The mask requirement is now considered by many to be dispensable – future-oriented pandemic research remains imperative.

Looking at Longer-term Issues

DFG extends Commission for Pandemic Research / Focus funding has proven effective

The DFG has extended the mandate of the interdisciplinary Commission for Pandemic Research until the end of 2023. Established in June 2020, the Commission was initially planned to last for two years, but is now being extended in view of the ongoing coronavirus pandemic. Its tasks include surveying the international pandemic research landscape, identifying research gaps and supporting evidence-based research in all pandemic-related subjects. Unlike many other expert panels on the coronavirus pandemic, the Commission is independent of any direct political advisory function.

"The Commission has addressed the highly dynamic pandemic situation on an ongoing basis. In this way, it was able to identify the most pressing issues that needed scientific support. Dialogue among Commission members was particularly interdisciplinary in character, thereby enabling a swift response to pandemic developments," said DFG President Professor Dr. Katja Becker. "Now we want to go on to address the longer-term issues and challenges. After all, the pandemic has far-reaching implications beyond the immediate consequences for health – areas in which research will be required for a long time to come. In addition, we aim to address issues of better pandemic preparedness and resilience."

The Commission has met for a total of 18 sessions to date, and there have also been numerous meetings of subordinate working groups. It has also issued several public statements: one example is the dossier "Know more – make more informed decisions", which provides information on vaccination, and a position paper in the field of aerosol research as well as statements on the need for action on health research data and for research into the topic of Long COVID.

In addition, the Commission organised the virtual international networking conference "Preparedness for Future Pandemics from a Global Perspective" in November 2021. The topics addressed here – such as causes and consequences of the pandemic, preparedness and the global dimension of the pandemic – are now to be pursued further as the Commission's mandate is extended further.

Another key instrument to emerge from the work done by the Commission for Pandemic Research was the COVID-19 Focus Funding programme that was specially created in 2020. Under this programme, a total of seven calls for proposals were issued to address particularly urgent issues that needed to be dealt with at short notice in all relevant disciplines. The programme offers a streamlined and accelerated funding opportunity to meet the current need for the rapid generation of knowledge on COVID-19 – though without compromising on the quality of proposals, proposal processing and the decision-making process.

The DFG has assessed the benefits of this new funding instrument based on accompanying monitoring, and initial findings have now been published in an interim report: Focus Funding has met with great demand among applicants at all career levels. They have used it primarily as a source of start-up funding for larger follow-up projects but also to advance ongoing projects. The Focus Funding programme also attracted more proposals for joint projects as compared to the DFG's regular individual project funding. Applicants and reviewers alike were largely satisfied with the time and overall formal conditions provided for the calls for proposals. The aim when setting up the programme to provide lean and accelerated funding was achieved by means of a reduced scope of proposals and a significantly shortened processing period. The average time lapse between receipt of a proposal and the final decision was just under three months.

www.dfg.de/en/service/press/press_releases/2022/press_release_no_04

Illustration: www.mpg.de/18173281/annaeherung-hinter-den-schlagzeilen © Wolf Lux

There was enormous outrage last December when the newspaper BILD published an article in which three academics were held personally responsible for the additional pandemic protection measures introduced shortly beforehand – under the headline "The Lockdown Makers" and featuring large-format portrait photos. It was not least the alliance of major science organisations that voiced strong public criticism of this reporting, saying that it was defamatory and violated the basic principles and rules of a free and open society. A few weeks later at the end of January, after the issue had reached the upper echelons of the BILD parent company Springer, representatives of academia and research organisations met with the BILD editorial board for a discussion panel which was broadcast live on the internet. This meeting gave rise to renewed criticism, this time directed at the academic community – on social media in particular – saying that the tabloid was given the chance to "whitewash" everything. There was no question of this being true of course, though BILD did not actually issue the "apology" that had been requested several times. At least the recently appointed editor-in-chief Johannes Boie (pictured above, 3rd from right) gave his assurance that the paper took the criticism seriously and would "no longer print" an article of this kind – apparently the piece "The Lockdown Maker" had caused some internal controversy, too. Nevertheless, according to Boie, academics who go public have to be prepared to face "pointed objective criticism". In response to this, Viola Priesemann (2nd from left) and Michael Meyer-Herrmann (2nd from right), two of those denounced by BILD, said that they were acting out of different motives and subject to a different risk as compared to politicians, for example, when they put their academic expertise at the service of policymakers and society. Finally, Otmar Wiestler, President of the Helmholtz Association (3rd from left), and Michael Hallek, a medical doctor from Cologne University and member of the German Council of Science and Humanities (far left), called for proper and fair support for this commitment and for the work and functioning of science in general. In the end, the group was not able to agree on everything but at least a dialogue had taken place. **fine**

Christoph Krekel and Carolin Heinemann

Travelling Artworks

Transport can cause damage to paintings and sculptures. How can such damage be recorded and distinguished from natural ageing processes? Art technologists, conservators and technical optics experts rely on a technique to compare high resolution 3D models from before and after delivery.

William Hogarth's famous engraving "Time is Smoking a Picture" shown on the left, dates back to 1761. It shows Chronos, the god of time, sitting on broken sculptures, blackening a painting with smoke from a pipe and slashing it with a scythe. It is an allegory that illustrates how works of art are subject to ongoing deterioration.

Light and oxidation, climate variations and vibration, the general interplay between energy and entropy, do indeed cause artworks to change very gradually. Minute ageing processes add up and cause our cultural heritage to change and decay, playing an even greater role than catastrophic events such as the fire at the Anna Amalia Library in Weimar in 2004, or the collapse of Cologne's city archives in 2009.

All of our cultural goods are going to disintegrate, sooner or later. Even those made of stone or metal. Even the pyramids. In the very long term, it will be impossible to stop this metamorphosis of the physical properties of our cultural heritage due to the passage of time. Nevertheless, it is the central task of conservators and conservation researchers to counteract the impact of time. Museums in particular pursue the mission to preserve these art objects. In the sense of Hogarth's engraving, museums are machines designed to stretch time by minimising environmental influences, in order to conserve the material manifestations of our cultural heritage for as long as possible, and to pass it on to future generations. Time is not allowed to smoke at the museum!

But is this really the case? Of course not. Much in the way that some pubs have smoking rooms, there are processes at museums that actually accelerate the pace at which artworks change. Temporary exhibitions and the corresponding transport in particular can cause artworks to age at a faster pace, even when carried out with utmost care. This is due especially to mechanical strain and abrupt changes of relative humidity. The interdisciplinary DFG-funded research project "Material changes to artworks caused by transport: studies to detect and distinguish transport and age related damage to artworks

Scan from „Hogarth's Graphical Works" / Wiki Commons

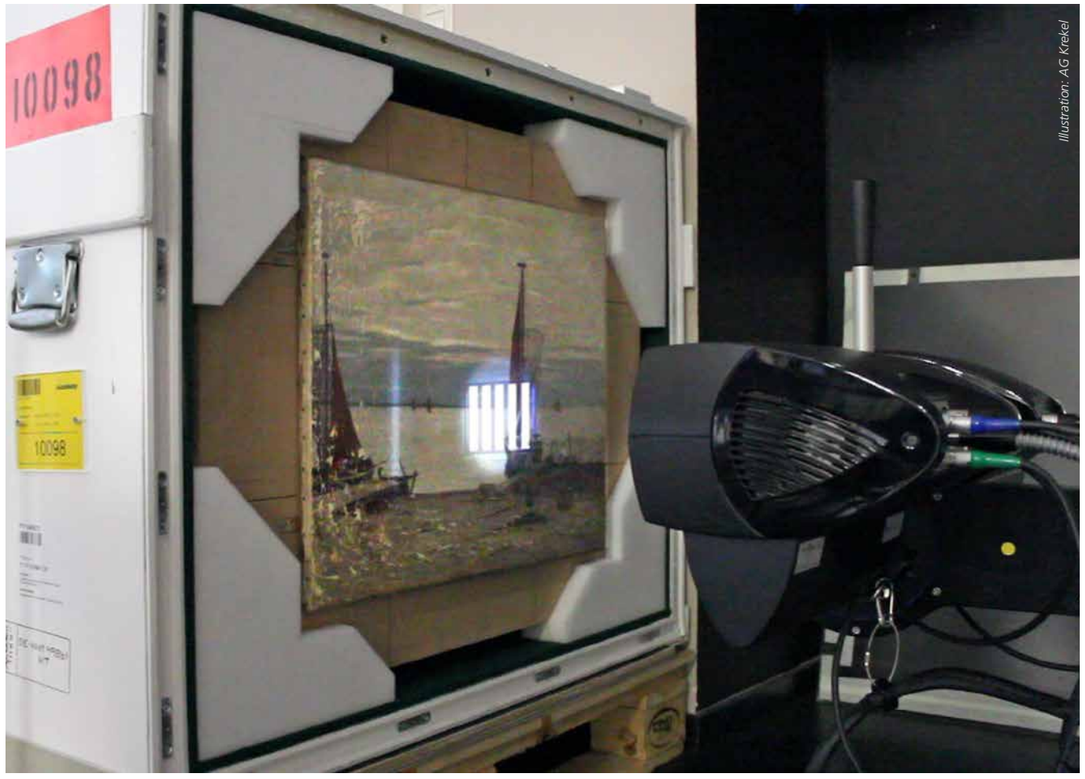


Illustration: AG Krekel

A painting is examined using 3D white light fringe projection.

(3D_artscan)" that is based at the Stuttgart State Academy of Art and Design and the Institute of Applied Optics at the University of Stuttgart, is dedicated to recording and assessing these minute changes caused by transport for the first time. High resolution 3D models of the items' condition before and after a transport event are compared automatically for this purpose. The project's objective is to conduct fundamental research of damage mechanisms, to reveal them and to allow for targeted improvements to procedures employed by museums.

Would it not be more sensible to just not have any special exhibitions at museums, since these can accelerate the ageing processes of artworks? Not at all! Temporary exhibitions are an expression and a tool of art research. They are addressed at an audience that is generally unlikely to visit a museum outside an elaborately marketed special exhibition. The role of museums as institutions would be called into question, if there were no special exhibitions. They are absolutely essential.

However, a survey conducted by the Institute for Museum Research in 2010, showed that the number of exhibitions held in Germany had almost quadrupled from 2,590 in 1990 to 9,145 in 2008, in addition to becoming ever bigger and more spectacular. This gives rise to greater mobility demands on cultural heritage than ever before, which is manifested in a high number of art transports. A dialectical conflict results between the desire to popularise art in society and to communicate findings from the field of art research on the one hand, and the museums' duty to conserve artworks on the other hand.

Up until now, material changes that occur during art transport have been identified visually by qualified conservators through a subjective evaluation of the condition before and after transport. Material changes on a microscopic scale remain systematically undetected with this approach. The same is true for any changes that occur below an object's surface. The "3D_artscan" project is dedicated to the examination and exploration of the impact of transport using high resolution 3D technology (known as 3D white light fringe projection) to compare the condition of an object before and after transport. Any damage below the surface is, for example, detected using a method called shearography.

It has been demonstrated in the context of the project that even minimal changes to relative humidity in an area of 4 percent, can cause changes to aged paint layers. What's more: if such a change of humidity occurs repeatedly, irreversible damage is caused. Our methods have enabled us to produce imaging evidence and to measure this impact for the first time.

This data alone has a (museum) policy dimension: in recent years, the standards for the so-called climate limits, that is the permitted variation of relative humidity and temperature, have been subject to debate, owing to the high energy demands associated with air conditioning in museums. An association of directors of international museums, the "Bizot Group", has drawn up a new guideline, aiming to reduce the carbon dioxide emissions produced by museums. However, the measured data from this research project shows that this generally desirable modification is hardly compatible with the requirements for conserving

The painting on the left as a montage showing its front (right half) and back (left half). A few bags of silica gel, used for humidity regulation, can be seen on the back.

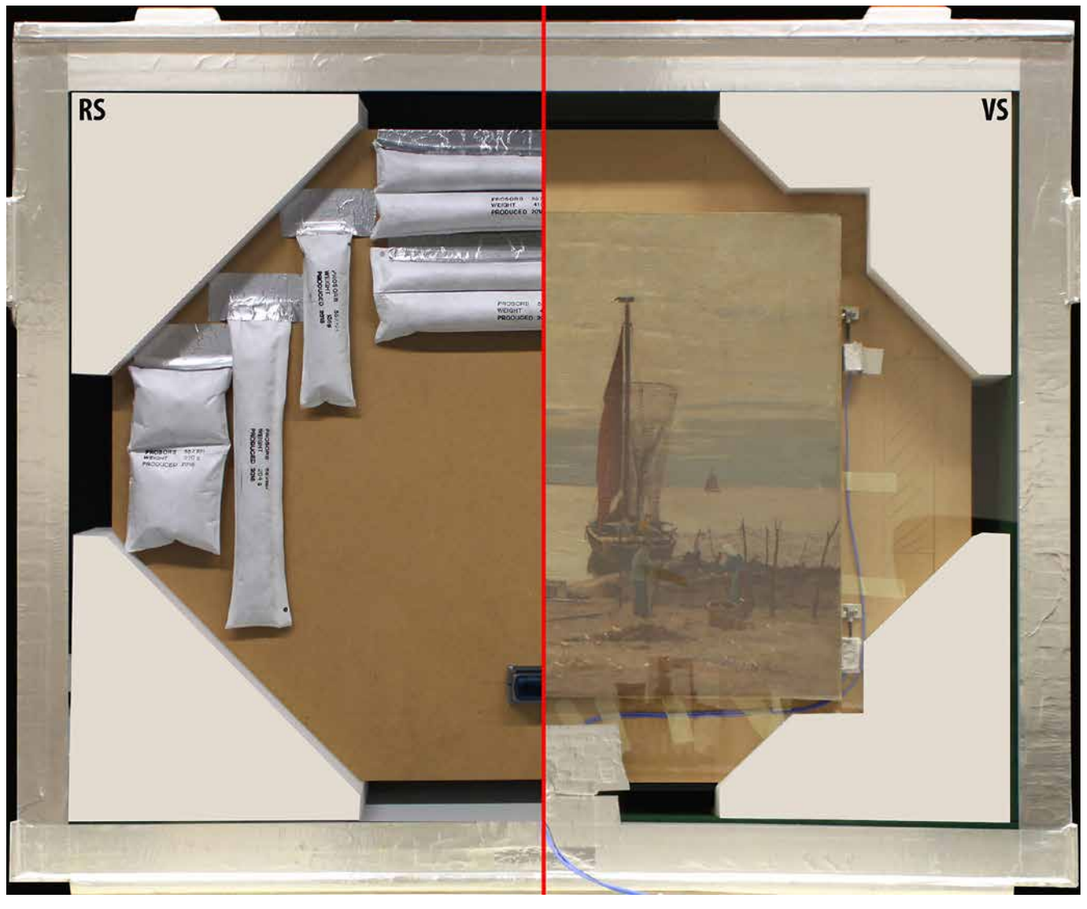
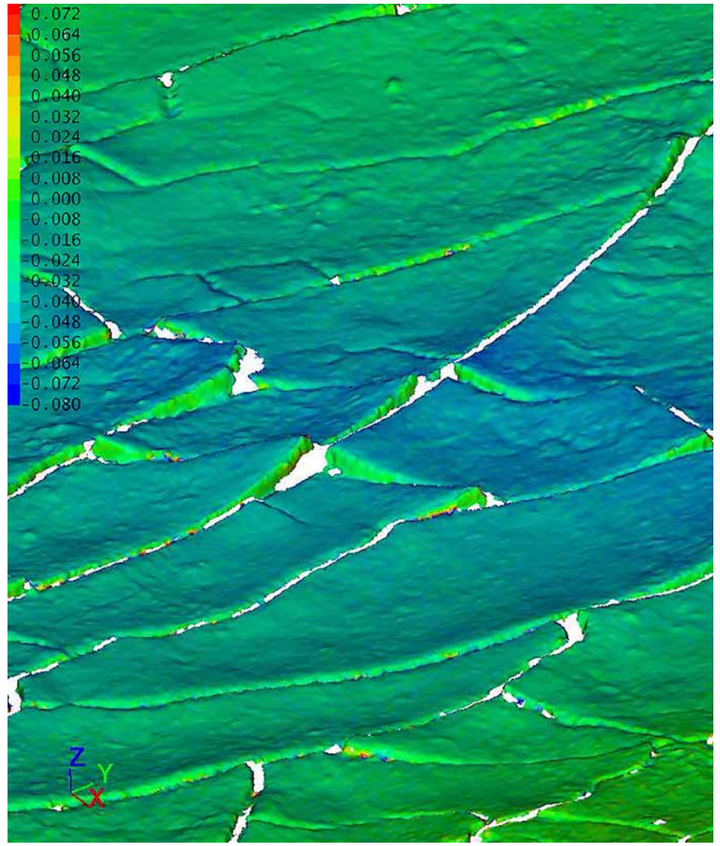
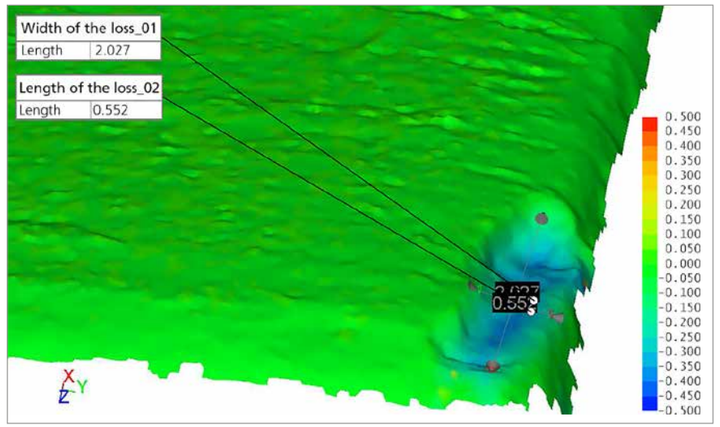


Illustration: AG Krekel





Top: Detail of a false colour image, visualising the damage on the paint layers. Bottom: The loss of the paint layer near the edge of the painting caused by transport is visualised in the 3D model, allowing for its size to be precisely quantified.

Illustrations: AG Krekel

artworks. Increasing the permitted range of climate values would therefore speed up the development of damage to paintings! The motto for indoor climate in museums is: "Stable is safe". This means that a clearly desirable reduction of energy consumption must be achieved in other ways, such as through museum construction.

The high resolution 3D technology was also used to provide evidence of the formation of transport related micro damage to a paint layer. In the first step, the initial condition of the object was measured using the 3D fringe projection scanner. Following transport, the artwork's condition was measured again. A tiny change was detected after the transport, in the form of a rising piece of the paint layer, known as a flake. The object was measured again, after another transport event. A quantifiable loss of the paint layer was detected at said spot: transport damage had occurred.

Based on this experiment and many others, methods and examination procedures are developed and validated step by step. These can help to assess damage to paint layers caused by mechanical and hygric (related to humidity) stress. For the first time, we now have a set of methods for researching the contributing factors to ageing processes of cultural goods, based on objective, three-dimensional image data.

This achievement forms the basis for more objective transport monitoring processes. Apart from relative humidity variation, it is in particular mechanical stress, such as vibration, that causes changes to paintings. However, what is the nature of such mechanical stress? To what extent do we need to take the paintings' natural frequencies and resonance into account? The experiments showed clearly that there is no simple and direct connection between stretcher frame acceleration and fabric acceleration, owing to the dynamic properties of paintings on canvas.

The data also has the potential for initiating a philosophical – if not political – debate: a 3D fringe projection scanner can also detect micro-changes that could not be examined to date, and were usually regarded as "natural" material ageing effects. The step into a new dimension of damage analysis therefore requires for the terms "material ageing / changes" and "material damage" to be discussed, as these are not clearly defined to date and not clearly delineated from one another. Assessments of actually occurring damage and a categorisation to determine to which extent changes can be tolerated in the context of exhibition activities, have not been performed sufficiently in the past. The original objective of the research project had been to explore a tool for documenting transport related microscopic damage to artworks. However, as this work progresses, it is becoming ever more obvious that the three-dimensional imaging approach is promising to become the basis for understanding ageing processes of artworks in general. If the results of this project can be put into practice, Chronos will find it slightly harder to continue his destructive work at our museums in the future.

The method of light fringe projection can be used to digitise and precisely measure not only paintings but also sculptures, to detect even minute damage caused by transport.

Illustration: AG Krekel

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Petra Sußner and Susanne Baer

In-between Spaces

European asylum law: borders are constantly contested and do not stand still. National borders enclose a state territory, but they are also places of opening: it is here that gender relations are negotiated, and people experience both inclusion and exclusion. Thus, there is a lot at stake for both individuals and social groups.

Illustration: OSTKREUZ / Pepa Hristova

Borders, gender and attempts to get things moving – a little girl in an in-between space that symbolically visualises the situation of refugees – as omnipresent as it is precarious – between borders of stone and glass. The 2012 photo by the agency Ostkreuz is entitled "Labyrinth of Glass: Child Retention Centre".

From a formal legal perspective, borders in the modern world order are matters which concern sovereign nation states: it is the latter who decide whether, why and how long people are allowed to stay on their territory. Those who do not meet the requirements for "legal" residence are rejected, returned or deported – their stay is terminated.

This sovereignty is constrained by the ban on refoulement under international law, which is a key element of asylum legislation: if the situation in the state of destination constitutes a violation of human rights, even sovereign states may be prohibited from taking measures to terminate residence in individual cases. The threat of torture is paradigmatic for how permeable sovereign borders can and must be under international law in an emergency.

From the Europeanised and globalised perspective of Germany today, the principles underlying this opening and closing process are complex. At the core of international legislation, the Geneva Refugee Convention (GRC), which came into force in 1954, prescribes that all signatory countries must guarantee a basic set of rights to all asylum seekers that fall within its jurisdiction. The 149 contracting states carry out asylum procedures to determine who is to be classified as a refugee in individual cases. In the EU, the Common European Asylum System (CEAS) regulates this procedure as well as the conditions under which subsidiary protection – subordinate to refugee status – is granted, and the preconditions for admittance to the host country. Of course, in addition to this – and in a sense always first and foremost – national rules apply.

As such, each individual asylum case reflects the interplay of a national border with its limiting effects on human rights within a legally pluralistic (or: multi-normative) regulatory regime. The legal analysis could well end there: the situation is complicated enough as it is. However, new perspectives open up when law is understood not only in the formal and juridical sense (i.e. derived and contextualised on a moral and ethical basis) or dogmatically – as a specific set of norms – but rather as a sphere in which a specific type of negotiation takes place that ideally includes interdisciplinary aspects.

In very real terms, borders do not stand still. Who holds Hannah Arendt's proverbial "right to rights"? Whose right to remain in a country must be tolerated? Who else should be included in the group of beneficiaries of such a right, and why? Whenever people cross borders, they challenge them. Many seek protection because they are individually vulnerable. But this act can easily turn into an issue that is not limited to their individual identity: the question of social context is always relevant – which "social group" they belong to, whether this collective exists or should exist and how it is defined. At the same time, it calls upon the collective of those who are being asked to provide protection: who a society opens its borders to says a lot about that society – its values and commonalities, especially when the opening of a border functions as a human rights necessity.

These manifold considerations taking place at a border now also explicitly take account of sex, or more comprehensively, gender. This is the most recent category of persecution to be included in the CEAS asylum canon, tested in the courts by refugee, feminist and human rights initiatives in the 1980s and 1990s. It has since been normatively established in the Qualification Directive 2011/95/EU and in § 3b Asylum Act (AsylG) as a basis for protection.

In abstract terms, the individual case is the smallest unit in the in-between space; the very place where social context is also negotiated, where a court ruling amounts to an iterative legislative statement by the receiving society as a wider collective, and where regulation is a broad-based normative step. Even within the context of the status procedure, which primarily seeks to clarify the subjective legal position of individual asylum-seekers, the fundamental risk prognosis anchored in human rights links the individual case to the attitude of the collective: is the purported danger from which claimants are seeking protection found to be real and is it considered severe enough to require the border to be opened? How is the "group" to which the claimant belongs actually faring in a specific region?

The fact that aspects of gender are also included in these considerations amounts to an achievement in itself: for a long time, gender perspectives did not form an explicit part of this assessment. The paradigmatic image of the politically persecuted male typically determined the notion of "right to rights", albeit implicitly. Gender-specific hazards to women were considered insignificant, and the women in question were often regarded as ("economic") migrants

who were dependent on men for their residence status, too. This gap in protection is rooted in the Geneva Refugee Convention itself, not least because it has nothing to say about gender. In terms of cultural history, this is neither a coincidence nor an isolated case. Modern European law is not only traditionally organised according to the notion of sovereign nation states; it has also been focused on individual male hegemony and hetero-normative legal subjectivity.

The Convention was drawn up after the Second World War, in response to the problems experienced by millions who had been displaced by National Socialism and European fascism and were left without rights. In fact, gender crime, namely the systematic persecution and murder of women, was certainly an issue already raised as early as the time of the Nuremberg Trials (as well as at more recent tribunals of international criminal law). But in the negotiations on the GRC, as becomes clear from the protocols, gender was still considered a matter of independent national concern, whilst homosexuality remained criminalised in many of the states leading the negotiations including the USA, France and Great Britain; as a result, this group was far removed from enjoying any protection at all.

Here, change only came about slowly, initially through the courts. Women's rights as human rights and the right to a homosexual private life have been litigated in asylum courts. The courts have drawn on the open-ended character of the Geneva Convention – the phenomenon of the "social group" in particular – to make the gender perspective beyond the masculine ideal a compelling aspect when it comes to border opening. But can this be regarded as an unmitigated success story?

Several questions arise here. The recognition of gender-based violations as grounds for a claim of asylum relates to how and for whom the border becomes permeable. This does not however establish whether the border will actually be opened in an individual case. There is a void here – again rooted in cultural history – and this is an issue that has been escalating critically since the summer of 2015. Thousands of refugees die in the attempt to cross the Mediterranean Sea every year. Europe's borders are currently considered to be particularly deadly. In political debate, fixed positions clash; in particular, irreconcilable populist demands for complete border closures have become inflated. These voices make use of the gap in protection opened up by the cultural and historical primacy of sovereign nation states which has been created by the interplay between border sovereignty and non-refoulement under the regulatory regime of the GRC and the CEAS: the main issue is that individuals only enjoy protection once they have managed to enter the safety of EU territory. And that is by no means a straightforward undertaking.

Attempts to create legal opportunities to enter EU territory in the aftermath of the Convention negotiations have so far been unsuccessful. And even as refoulement at the border is inadmissible under human rights law, one thing remains clear: will someone on a ship really take time to consider the merits of an asylum application that comes from a claimant arriving on an inflatable dinghy? And who will take account of the gender-specific grounds for persecution that may have gradually found their way into the administration of justice and legal norms, yet are still subject to constant renegotiation?

On arrival in the EU, the sheer volume of regulations that apply is steadily increasing, but again, this can by no means be considered an unmitigated success. The Reception Directive 2013/33/EU sets minimum standards for the waiting period in the asylum procedure, requiring

Key human rights documents relating to the Geneva Convention on Refugees on display as part of the exhibition entitled "Displacement" at Bern Historical Museum in 2018.

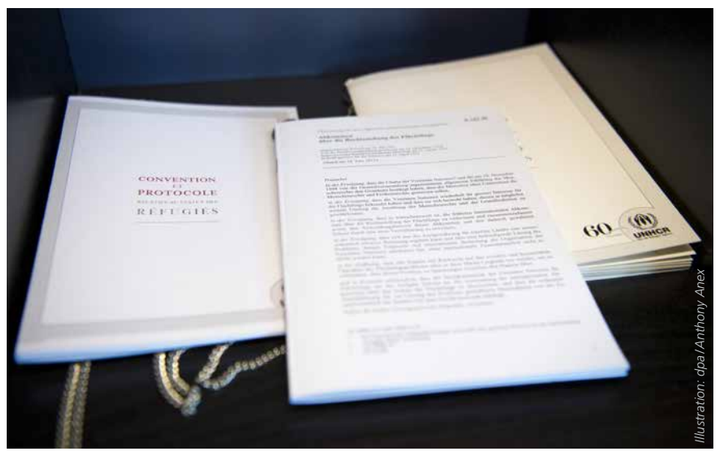

Illustration: dpa/Anthony Anex

Illustration: dpa/NurPhoto

Fear and trepidation at border fences, hoping for refuge in makeshift tents: women waiting to be registered at Kara Tepe refugee camp on the island of Lesbos, September 2020.

states to protect individuals against gender-specific risks. However, the reality experienced by claimants is often far removed from this. People arriving on the Greek islands are by no means safe, and there is enormous pressure on governments in deciding whether the borders should be opened or remain closed. Human rights achievements thus become eroded in the iteration of individual cases. Whilst gender and sexuality are now the subject of compulsory and independent investigation during the status procedure, the CEAS still does not provide for an independent procedure to identify gender-specific needs in reception areas, even though fundamentally, these must also be afforded protection.

What remains are humanitarian interventions to rescue "women and children" from camps such as Kara Tepe on Lesbos or Lipa in western Bosnia. Where such interventions achieve their aim, each individual case must be considered a success. At the same time, such interventions are often unable to consider the needs of eligible individuals in all their diversity, including gender: those concerned are still subjected to gender stereotyping in tacit relation to men, thus remaining essentially vulnerable and disempowered.

Once again, we can see how borders are permeable and constantly contested. Legal success in one instance is often accompanied by injustice elsewhere, as recognition is always negotiated individually. Even the French Revolution's great promise of *égalité* did not apply to the *citoyenne*, and the US Constitution's *we the people* was only true for certain white men. In asylum law, these limitations are repeatedly called into question.

Achievements in the in-between space are often particularly fragile. Legal rulings in individual cases and normative legislation of general validity must be regarded as contributions to a complex negotiation involving many parties, including the courts and other legal actors, states, organisations and individuals; most importantly the refugees themselves. This also gives rise to a multi-dimensional examination of notions of belonging, identity and identification – something that has long been familiar in the field of gender studies, i.e. the scholarly enquiry into gender relationships. It is at the borders that we can see just how much is in motion. In this in-between space, what matters is the fate of individual people and the question of what we mean when we say *we*. The law provides a multi-dimensional space within which this is negotiated.

Illustration: Die Hoffotografen

Illustration: Britney Majure

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Friedhelm von Blanckenburg

Life Beneath the Surface

Between the Earth's surface and the underlying rocks there is a thin layer of soil. This is the skin of the Earth. How deep is this skin? How do micro-organisms and plants interact with this dark world of rock? In the Chilean coastal mountains, geo- and bioscientists are answering these questions by investigating rock weathering – yielding insights on how the surface of the Earth will respond to the climate of the future.

Drilling operation under the blazing sun: in the semi-desert of Reserva Santa Gracia in Chile.

Illustration: AG Blanckenburg

The thin soil layer that we live on and that feeds us is also known as "the skin of the Earth". It separates the atmosphere from the world of rocks underneath. If we dig through this layer, we will encounter hard material after about one metre. This is former rock material that was altered by water and the atmosphere: "weathered rock".

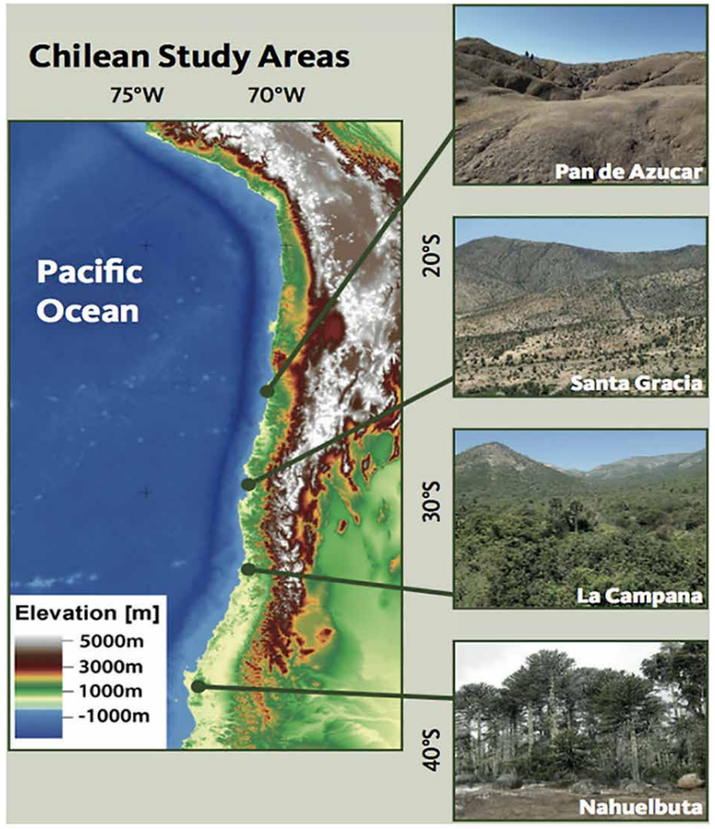
Groundwater is found about a dozen metres below the surface. A wide range of important chemical, physical and biological reactions take place in the few metres in between. This is why this area is also referred to as the "Critical Zone". The Critical Zone is the boundary layer between the atmosphere and rock that includes vegetation. But how deep is this altered zone? Is it inanimate or full of life?

There are two simple methods to find out how deep this zone really is: dig out the soil to reveal its profile, or search for its lower boundary in rock quarries. A German-Chilean research team of the Priority Programme "EarthShape – Earth Surface Shaping by Biota" (that studies the impact organisms have on the Earth's surface) chose the Chilean coastal mountains as a research area. Their goal: to explore the impact that life – that is plants, animals and microbes – has on rocks and how the world of rocks impacts life itself.

The Chilean coastal mountains offer ideal conditions to investigate these interdependencies. The landscape is characterised by a spectacular climate and vegetation gradient. Hardly any plants grow in the Atacama Desert in the arid north, where the surface is scattered with hard, red stained rocks. The humid south, on the other hand, is home to a robust rainforest where the rock is heavily weathered and covered by dark brown soil. The study regions stretch from the Atacama in the north through to Araucaria forests, more than 1,300 kilometres further south.

Working with heavy equipment: drilling into the Earth's "near surface" is taking place at Pan de Azúcar National Park in the Atacama Desert in Chile.

Illustration: AG Blanckenburg



Four locations, one research objective: researchers of the EarthShape Priority Programme are conducting their studies along the climate and vegetation gradient in the Chilean coastal mountains.

The researchers of the EarthShape project soon made an unexpected discovery: the Critical Zone turned out to extend far deeper below the soil layer than expected. Its lower boundary could not be found, even in 30 metre deep rock quarries. This gave rise to a number of new questions: Which processes enable it to achieve this depth? Is it due to geological processes such as tectonic fractures or to mineral reactions? Or does life itself help to extend this zone far beyond what was expected? We know from microbiological research conducted in ocean sediments that vast microbial habitats exist in permanent darkness deep below the ocean floor. Paradoxically, we still know very little about whether this type of "deep biosphere" exists in the subsurface of the Critical Zone.

In the second phase of the EarthShape Priority Programme, a team of geologists, geochemists, microbiologists and geophysicists from Germany and Chile set out to conduct geological drilling at all four sites along the EarthShape climate gradient. Drilling to a depth of up to 100 metres required elaborate fieldwork in tough conditions. A Chilean drilling company arrived with heavy drilling equipment. The researchers and doctoral candidates set up a field station to process the first samples. Water trucks were used to bring in thousands of litres of clean water to lubricate the drill. The desert sun shone relentlessly and workers and equipment were soon coated in dust, while the noise of the drilling machinery was deafening.

The team members also got to know the local residents of these areas in Chile, and learned about their frequently harsh living conditions. It is rather alarming that the vegetation in Central Chile is becoming ever drier, year by year. Water is a scarce commodity, for which the local farming population competes more and more desperately. In November 2019, the team was concerned to witness civil unrest due to social inequality: tires burning in blocked roads and tear gas used in the cities. The end of the campaign in March 2020 was rather turbulent as well, since the team made it back to Germany just in time, before all social activities and international flights were shut down due to the coronavirus crisis.

The research work carried out was only possible thanks to the drilling technology used, which is known as "wireline core drilling". A drill head equipped with fine diamonds, rotates at the bottom of a 13 centimetre wide tube and slowly makes its way into the very hard rock. The drill core, a pillar of rock that has been separated from its surroundings, is pushed into the tube, and pieces that are 1.5 metres long are pulled up in an inner tube using a wire.

Water is used to cool the drill head. This water has to be very clean to protect the rock that is extracted from a great depth against contamination with microbes from the world above. Things get interesting whenever the drillers extract a new 1.5 metre long core and the rock material becomes visible for the first time. It is much like reading an exciting book. Each core is a new chapter that may bring an unexpected turn of events, re-write the story told by the rocks and present new puzzles for the researchers to solve.

Even the initial inspection of the drill cores brought some surprising results: the weathered zone is actually up to 80 metres deep, before which there is no rock in its original state. This is much deeper than had been found in the few other drilling operations conducted around the world. In addition to this, it was found that at some locations, the rock is frequently broken or fissured. This might be caused by strong earthquakes, which have affected the Chilean coast for millions of years.

Drill cores from Santa Gracia, packed into "core boxes" for shipping. Rock fractures and weathering decrease with increasing depth (from left to right).

Illustration: AG Blanckenburg

Which processes promote weathering deep below the surface? The current hypothesis is that tectonic fractures allow rain water to penetrate the rock along with rock-altering reagents such as carbonic acid. But how do these substances enter the rock segments between the fissures? Atmospheric oxygen that enters the areas underground through the fissures may play a role here. It oxidises the iron contained within mineral in the rock, transforming those minerals into rust which requires a larger volume. This causes fine fractures through which the reagents can make their way to the inside of the blocks of rock. Furthermore, it may be the case that microbes – bacteria, fungi and archaea – are also being transported to deeper areas as passengers in the water that travels through the fissures. Cell reproduction is linked to chemical reactions and these can enhance the weathering of rock.

An important final question remains: where does the carbon come from that is needed for this proliferation of microbes? It does not exist in the granitic rocks. It may be harvested by microbes directly from the air or from carbon-containing minerals contained within the rocks themselves. Alternatively, it may be supplied from the living world of plants and microbes in the surface soils. If the latter is true, weathering deep underground would be linked to biological productivity at the surface whereas if the former is true, the sub-surface microbes would be independent of processes on the surface. The chosen climate gradient with its huge differences in vegetation cover, provides a suitable test site for this hypothesis, too.

However, this is not the end of the story. Preliminary results have already given rise to new questions: why does weathering extend to the greatest depth in the Atacama Desert, despite the fact that there is barely any water, which is usually the driver of rock weathering? Weathering at the southernmost and most humid site, meanwhile, only extends to a depth of 15 metres. Can these results be explained with feedback effects between initially independent processes that can be either intensifying or dampen weathering processes?

Various state-of-the-art research methods are used to answer these questions. These include geophysical methods using seismic and electromagnetic waves, geochemical and mineralogical analyses, as well as measurements of rare, naturally occurring isotopes. The number and species of microbial cells is determined by looking at DNA contained in the rocks, and laboratory simulations test whether the growth of cells from deep below the surface really affects minerals in the rock. The overall aim of the research is to comprehensively examine the hypotheses on the transformation of the subsurface and the role that organisms play in this transformation.

Beyond the research objectives of the EarthShape project, an exploration of the Earth's surface is also relevant to global challenges. Humankind will be using the layer immediately below the surface more and more: to gain rare raw materials that are needed for the energy transition, for storing energy such as methane and hydrogen, as well as for storing carbon dioxide arising from combustion. Knowledge of the processes that take place underground, and the examination of methods necessary for using these processes is therefore essential.

Last but not least, there are two ways in which the process of rock weathering has an impact on the Earth's climate: the greenhouse gas CO_2 is consumed by the chemical reactions themselves, albeit at a slow pace. Far greater is the amount of CO_2 that is removed from the atmosphere, via photosynthesis and other microbial metabolisms, by plants and soil microbes. Mineral nutrients that are released through rock weathering are required for this process. This means that the processes that take place just below the surface of the Earth, also have an impact on the future development of our global climate.

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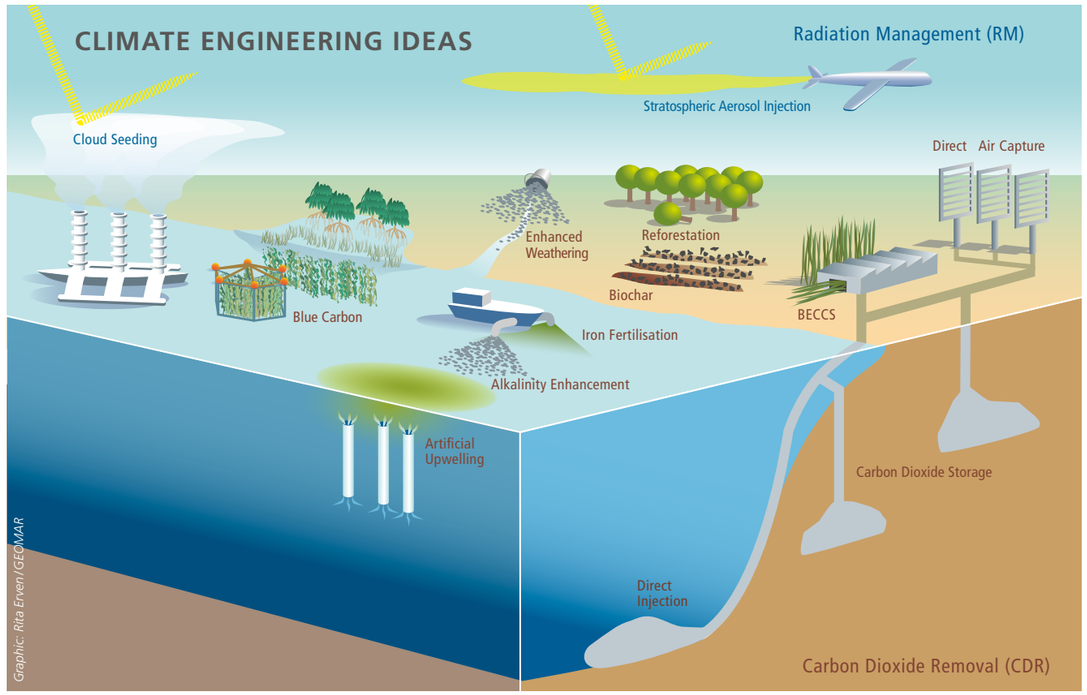
www.earthshape.net

Andreas Oschlies and Ulrike Bernitt



Let's Save the Climate! But How?

Climate Engineering: the scientific consensus is that even a drastic reduction of carbon dioxide emissions will not be enough to reach the promised climate goals. Possible approaches range from the removal of carbon dioxide from the atmosphere through to influencing solar radiation. The related potential and risks were reviewed in an interdisciplinary project.

History was made in Paris in December 2015: at a global climate conference, 175 states agreed to pursue the goal to limit global warming to well under 2 degrees Celsius. This "Paris Agreement" was an impressive diplomatic achievement. What has happened since is not nearly as impressive: global carbon dioxide emissions reached a new record level in 2019, and even an annual reduction of carbon dioxide emissions to a level as was caused by the COVID-19 pandemic in 2020, would no longer suffice to reach the climate targets. The emission budget that is left before the agreed climate goals are exceeded, is declining at a dramatic rate, and the same is true for the time we have left to prevent the existentially threatening consequences of further global warming.

The desired 1.5 or at least 2 degree goals are based on the most optimistic scenarios used in the 5th assessment report issued by the International Panel on Climate Change in 2013, and the special report published in 2018 regarding

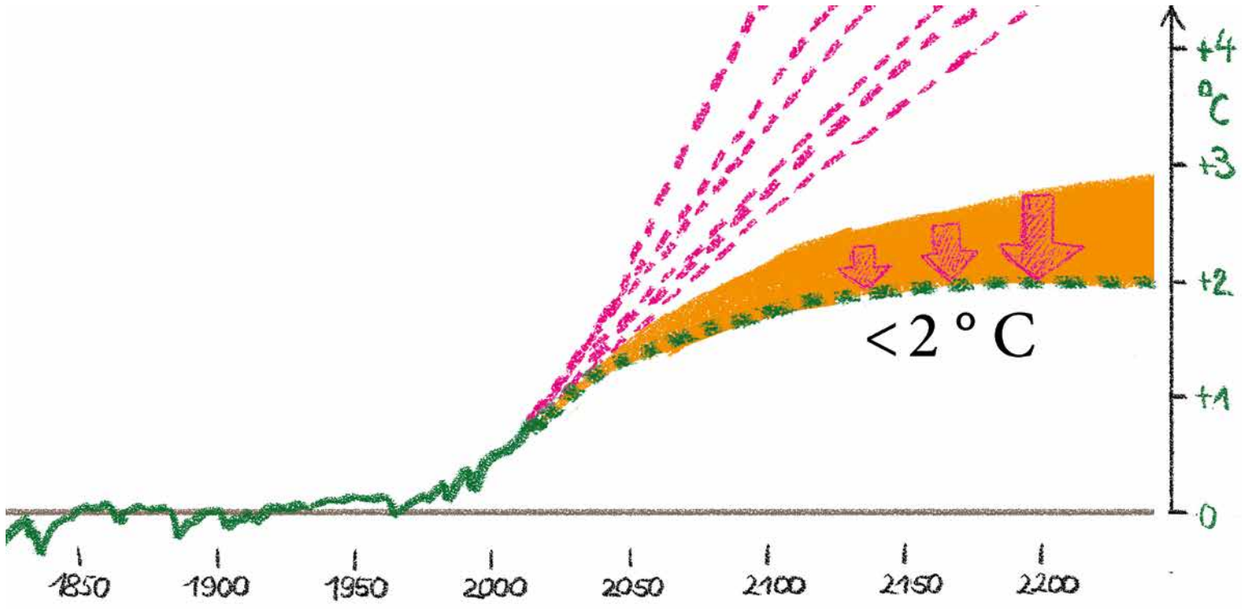
Left: Illustration of climate engineering methods that are subject to controversial scientific and political debate.

the 1.5 degree target. In any scenario, even a drastic reduction of emissions will not suffice on its own to reach the specified climate goals at this point. This is why climate researchers also factor in that in the future, humankind will be able to remove and safely store carbon dioxide from the Earth's atmosphere, on a large scale of several billion tonnes a year. The amount and speed at which the carbon dioxide will have to be removed from the atmosphere, increases with each year, in which a prevention of emissions is further postponed. But how can vast amounts of carbon dioxide be removed from the atmosphere to generate "negative emissions"?

There are various physical, chemical and biological approaches for removing carbon dioxide from the atmosphere, and storing it on land or in the ocean. Some of these carbon storage options are permanent, while others are merely temporary solutions. Trees fall into the latter category. When trees grow, they absorb carbon dioxide from the atmosphere and store it in the wood in the form of carbon – sometimes for centuries, depending of the tree's lifespan. The carbon can also be conserved for a long time when used as a building material. However, the entire carbon dioxide is released again, when the wood rots or is burned. A conversion into biochar might even allow for greenhouse gas absorbed by plants to be stored for thousands of years.

Geological storage facilities and the ocean are the most promising options for permanent storage. Geological storage forms include the storage of carbon dioxide in rock. Depending on the type of rock and the local conditions, carbon dioxide that is introduced in liquid form might even be converted into solid carbonate minerals. Geological storage is currently being discussed in relation to so-called direct air capture methods that provide for carbon dioxide to be captured using chemical absorbers ("artificial trees"), as well as with regard to bioenergy with carbon capture and storage (BECCS). Another approach that is being considered to allow for carbon dioxide to be permanently removed from the atmosphere, is to distribute alkaline substances – rock dust in particular – into the ocean. The objective here is to chemically neutralise the carbon dioxide that is dissolved in the seawater permanently, through weathering of the rock material, and to thus increase the ocean's capacity to absorb carbon dioxide.

Factual analysis: the political climate target of 2 degrees can no longer be realistically achieved, even if all opportunities for reducing carbon dioxide are exploited. A certain degree of excess warming would remain, as shown roughly in the form of the orange coloured area.



Such methods are often referred to as “climate engineering”, as the removal of carbon dioxide from the atmosphere on a large scale would constitute a targeted intervention into the climate system. The same term is also used to cover ideas concerning direct interference with the Earth’s radiation budget (“radiation management”), by preventing part of the solar radiation from reaching the earth, using aerosols distributed outside the Earth’s atmosphere, or by reflecting radiation back into space by brightening clouds, land or water surfaces. However, unlike carbon dioxide removal, this approach does not provide for the actual cause of warming (the high carbon dioxide concentration in the atmosphere) to be eliminated.

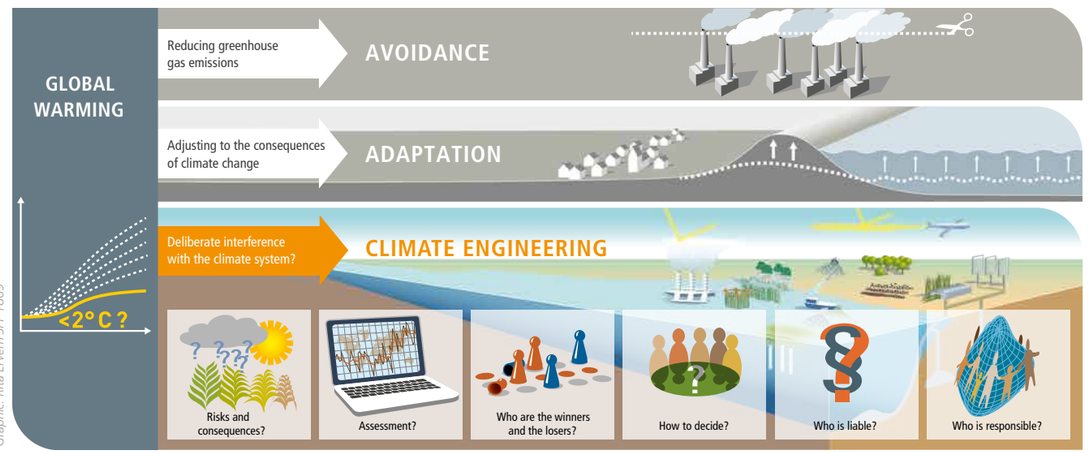
Over the past seven years, the risks, challenges and opportunities of climate engineering have been explored in an interdisciplinary manner, in the context of a DFG Priority Programme. A key aspect of this Priority Programme was that any research should be conducted solely for assessment purposes, and not for developing or even applying climate engineering techniques.

One of the findings of the interdisciplinary research programme was that the potential of the individual measures appears ever smaller, the closer they are examined, while the sum total of side effects appears all the bigger. This is the case for seemingly utopian methods, such as solar radiation management, as well as for supposedly “green” methods, such as reforestation and BECCS. Land-based approaches that are based on biomass production have an impact on the colour of the planet, on the water cycle and on biodiversity. Demand for water, nutrients and space can give rise to conflicts with the areas of farming and food production. There are still many unanswered questions: Can large-scale applications ever be compatible with nature conservation and other sustainability targets? How stable is the long-term storage of carbon dioxide provided for by these measures?

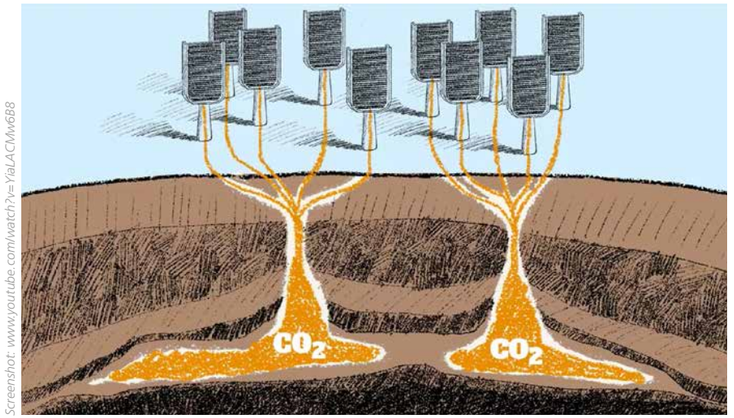
Based on current knowledge, we will need to safely remove billions of tonnes of carbon dioxide from the atmosphere every year by 2030, to be able to still achieve the specified climate targets. This means that we are under considerable pressure to act and explore all possible options for capturing carbon dioxide. In addition to potential, risks and side effects, practical usability, scalability and controllability must also be examined in the context of applied research. Society needs to be actively involved, and the development of appropriate infrastructure and political control and regulation mechanisms must be investigated at full steam.

Owing to the fact that there are no scientifically sound, socially accepted and politically feasible roadmaps for achieving the climate targets, there are also researchers who are offensively considering increasing research into the field of radiation management. Such work is mostly based on the assumption that emissions in excess of the remaining emission budget can be temporarily

Global warming is a clear fact, while the possibilities related to climate engineering are still unclear. Many questions are still unanswered, as the risks and opportunities related to the different approaches and methods have not been fully assessed.



Graphic: Rita Erven/SPP 1869



Screenshot: www.youtube.com/watch?v=YaLACMw688

From an animated film by the SPP 1689: the “direct air capture system” may constitute an option for removing carbon dioxide from the atmosphere and storing it underground. A problem is the anticipated high need for energy. Can this be solved?

compensated for by reducing incident sunlight, until enough carbon dioxide has been removed from the atmosphere. “Temporarily” in this case means several decades or even centuries, in which reliable operations, simultaneous carbon dioxide removal and viable international regulations for handling side effects must be ensured. A continuously high carbon dioxide concentration in the atmosphere would cause rapid warming, if solar radiation management was to be abandoned prematurely. Side effects of this type of solar radiation management would be caused, in particular, by the disparate working mechanisms of carbon dioxide (affecting thermal radiation that is relatively evenly distributed around the world) and the envisioned distribution of aerosols (most effective when the sun is shining, i.e. in the tropics by day, and has no effect during polar winter).

There may be significant deviations in regional climate and therefore weather and extreme events under solar radiation management, compared to a world without radiation management and a lower carbon dioxide concentration. This would lead to ample room for conflicts among the perceived winners and losers.

Unlike solar radiation management, the removal of carbon dioxide from the atmosphere could be stopped at any time. As long as the captured carbon dioxide is stored safely, there is no potential for adverse effects on the climate system. To allow for effective carbon dioxide removal, it is therefore of paramount importance to find safe long-term storage solutions, as provided for by accelerated weathering of stone or carbon capture and storage (CCS, storage in geological structures). This also means that we must address the issue of CCS, which has so far been a taboo topic in Germany.

One thing is for sure: Carbon dioxide removal is not a suitable means to quickly interfere with the Earth’s climate processes. It will take many years or even decades to capture the necessary amounts and to achieve an effect on the climate. Carbon dioxide removal methods must therefore be applied in a timely manner and for an extended period. In addition to this, the permanent nature of carbon dioxide storage must be monitored for many of the processes. Removal of carbon dioxide from the atmosphere in any way is not technically mature at this point. The development and installation of the corresponding infrastructure may take decades, and the same is true for the necessary social choices. From the point of view of climate research, it has long been clear that the climate targets can no longer be achieved without capturing carbon dioxide. It is urgently necessary for science and academia, policy makers and the civil society to engage in a differentiated and targeted debate, to assess the individual approaches and to make sustainable and expedient decisions about how we would actually like to reach the pledged climate targets.

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Further information: The brochure “Climate engineering and our climate targets: an overdue debate” is available via the SPP 1689 website: www.spp-climate-engineering.de/index.php/news.html

The Deutsche Forschungsgemeinschaft

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For more information, visit www.dfg.de/en

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A war is now in progress that is so violent and brutal that it has even pushed the pandemic out of people's minds and out of the headlines for the time being. It might not be a bad thing to be reminded that our livelihoods have long been threatened in other ways. "The time to act is now" – this is in any case the conclusion and message of the Intergovernmental Panel on Climate Change (IPCC) from early April. Realistic climate targets must be redefined and climate protection measures must be implemented and monitored more consistently, supported by a transformation of the economy and energy supply – even in times of war and crisis. Political and academic observers have long agreed that sustainable developments are linked to overarching challenges, but must be tackled within a concrete framework, and starting on our own doorstep. In view of this, the DFG intends to give greater consideration to dimensions and aspects of sustainability in its funding activities in future. To this end, the Executive Committee decided at the end of 2021 to establish a Sustainability Commission under the leadership of President Katja Becker. In March, the 20 Commission members representing the entire breadth of subjects came together for their first session. The initial focus of their work is on issues of ecological sustainability. The Commission is to present recommendations for sustainable action in the summer of next year. The agenda is already well filled.