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Invited Viewpoint

The scientists' responsibility in communicating the sustainability crisis

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ABSTRACT

Humankind and, in general, all life on earth, face a fundamental sustainability crisis. We have realized many decades ago that both our sources and our sinks on our planet are limited. International treaties have been adopted, panels have been formed and assessments have been published. Yet, almost all nations regularly fail to comply with their goals. Many potential barriers to swift actions exist, and sustainability in its many facets reveals complex interdependencies and rebounds. Humankind relies on an infrastructure in terms of energy supply, housing, and others, which take decades to change. At the same time, we face tipping points, which describe an irreversible acceleration of degradation of our fundamental life's resources. This concerns not only the climate crisis, which is visible in so many nations with floods and heat waves and a surge of new temperature extremes and costs due to mitigation and adaptation. No, the problem also lies in a set of planetary limits, including a terrifying loss of agricultural soil, an increasing level of acidity in the oceans, enhanced nitridation, and loss of biodiversity and natural habitats. In this situation, it appears obvious, that scientists, meaning all scientists beyond our representatives in international panels, need to respond. We need to inform ourselves across the disciplines and disseminate available information into society. We need to spell out that a transformation of society is required combining technological advances and a change in lifestyle with a reduction in demand for our planet's sources and sinks.

Introduction

The most commonly used definition of sustainability was provided by the Brundtland Commission, established by the United Nations in 1983 and named after the first chairperson, Gro Harlem Brundtland. In the Brundtland report [1] from 1987, sustainability was defined as "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" Interestingly, there was a second, more involved, definition, which is less frequently cited [2]: "*Permanent*

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development demands a process of change, through which the use of resources, the goal for investment, the direction of technological development and institutional change stand in harmony and enhance the current and future potential to fulfill the human needs and wishes." It got less frequently quoted as it contains a holistic behavior change, which turned out to be less consensual in the political arena.

Historical aspects: 1460–1960

Many societies encountered the problem of sustainability early on in their development. On the eve of the early modern age, states needed timber for their merchant fleet and navy ships. They also needed charcoal as fuel for the metallurgical and glass industry. The senate of the city-state Venice recognized this demand and decided on several provisions governing the use of communal forests, including a rotational restricted harvesting scheme in 1476. These rules became the most commonly cited precedent for all future sustainable forestry management [3]. On the flip side, Venice continued nonsustainably harvesting forests across the Adriatic. Hence, sustainability was only applied to the metropole, but not to the colonies.

Similarly, the book "Sylva" by John Evelyn [4] is considered one of the most important precursors on the discussion of sustainability. It is one of the first two books by the Royal Society and was published in 1664. Evelyn received a lot of attention for his assertion that continued deforestation would lead to the downfall of the British fleet.

John Tyndall, an experimental physicist from Northern Ireland, has been credited for his first measurements of the infrared absorption of different gases in 1869 [5]. He observed that water vapor, carbon dioxide, and methane exhibit very strong absorption. In the early twentieth century, the recognition came that without these gases, the surface temperature on planet earth would actually be considerably lower, meaning that the concentration and the lifetime of these greenhouse gases have to maintain a subtle balance for all living creatures.

Still, in the late nineteenth century, Svante Arrhenius [6] undertook the monumental task of predicting global warming. He was described as taking a full year for his computations and quantified that our planet would heat up by 5–6 °C if the carbon dioxide concentration in the atmosphere doubled. He also considered the time frame it would take by firing coal and wood to release such huge amounts of CO_2. As his computation yielded a time frame of about 3000 years to reach such levels, he mistakenly concluded that his work may have been irrelevant for the near future.

Sustainability crisis

The limits to growth

Environmental concerns were brought to the general public for the very first time by Rachel Carson with her book "Silent Spring" in 1962 [7]. Ten years later, the book by the Club of Rome, "The limits to growth" was published [8]. The book offered scenarios for twelve different futures of the world on planet Earth. The model used for the report was "World3" and involved hundreds of parameters. But it concentrated in a very coarse, aggregated form on five sectors: Human population, non-renewable resources (minerals), renewable resources (agriculture), capital resources, and pollution. It reached a simple conclusion: if the physical growth (which is now termed growth of ecological footprint) continues, used resources will get scarce, leading to drainage of resources and increasing pollution. As was noted in the 40-year update [9], the general trend proved true, but the bigger threat for humankind is suggested to stem from the limits of sinks and less so from sources. This means that the Earth can absorb the disposal of human activities (carbon dioxide, nitrogen, microplastics, etc.) to a lesser degree than it can provide the sources for our products [9]. These predictions based on computer simulations had been continuously updated and contrasted with reality. A more recent prediction points out that most scenarios are characterized by a peak of population, available food, and industrial output in the time frame between 2030 and 2050. In addition, there is but one scenario, based on changes in societal values and priorities, which would avoid collapse and stabilize human welfare on a high level [10]. However, the window to transgress to this path is closing fast.

In a publication of 2009 [11] and then later of 2015 [12], the argument has been put forward that the advent of the Anthropocene [13] signifies that our planet is experiencing global environmental changes driven by humankind. The authors identified 9 planetary boundaries [12] defining a safe operating space [11]. Steffen et al. [12] provided a science-based analysis of the risk that humankind's developments

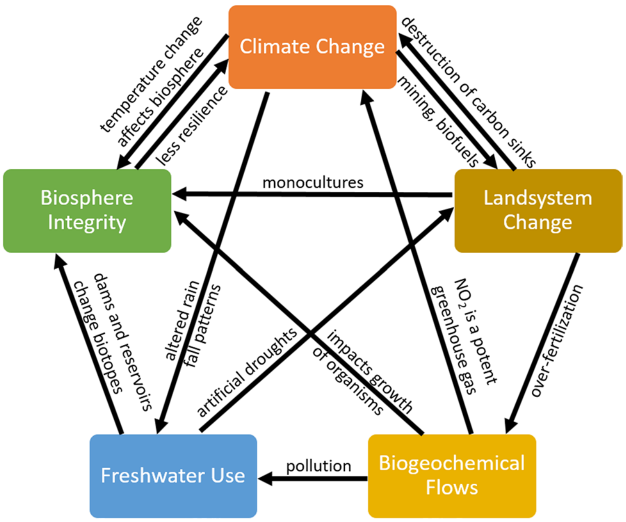

Figure 1 Schematic featuring interrelationships of selected planetary boundaries in an exemplary manner. For a more extensive list see Table 1.

will destabilize the Earth system on a global scale. We suggest that the general public is still occupied with a focus on climate change due to an increase in greenhouse gases like carbon dioxide and methane. Hence, it may be led to believe that technological advances in energy conversion, transport, and storage would be game changers. Valid as these efforts in these fields are, they may not solve the issue of the other 8 planetary boundaries. What is more, successes toward enhancing our safe operating space in one limit may negatively impact the other limits [10]. As this readily becomes complex, we focus here on the four Earth system processes, which have been identified in 2015 as having then already transgressed the planetary boundaries: climate change, biosphere integrity, land system change, and biogeochemical flows. To illustrate their interaction, we demonstrate some interdependencies. Next to the four Earth system processes, we add one, which became more prevalent only in recent years and provides very transparent interdependencies: freshwater usage. The loss of fresh water has recently been quantified to a certain degree [14]. For example, in the European South, it has led to vibrant conflicts of interest between farmers demanding water for irrigation, tourism (golf courses, etc.) to maintain their infrastructure, enterprises needing water for production processes, and citizens trying to water their gardens or simply getting drinking water. As can be witnessed from Fig. 1, there are multiple correlations between the Earth systems presented. These connections are to be seen here only as exemplary descriptions and are not meant to be final and complete. Their representation in other form is also tabulated in Table 1 to allow for a more tractable discussion. The interrelationships between the many planetary boundaries are considered one of the reasons that scientists need to study the sustainability crisis from

Table 1 Interrelationships between selected planetary boundaries. Note that this Table is meant to provide only examples without claim for completeness

Impact on	Impact from				
	Climate change	Land system change	Biosphere integrity	Biogeo-chemical flows	Freshwater use
Climate change		Less sinks Biofuel	Less resilience Less sinks	NO2 Energy Consumption	Building dams releases CO2
Land system change	Decreased productivity			Over fertilization	Irrigation Artificial droughts
Biosphere integrity	Ocean acidification	Monocultures Less natural habitats		Enhanced growth	Less natural habitats
Biogeo-chemical flows	Erosion Changed nutrient cycles	Increased use of fertilizers			
Freshwater use	Altered rainfall Cooling water H2 hydrolysis	Less water stored in soil Faster run-off	Biological imbalance	Pollution of freshwater sources	

different scientific vantage points and need to communicate to the general public as such.

The planetary boundaries have been quantified into a single data point and have been distinguished for Earth and each country separately. This value is a date during the course of the year and has been termed overshoot day [15], defining the day when humankind's resources needed during one full year have been used up. Although this date appears very arbitrary and needs to include emissions of carbon dioxide as well as nitrogen, etc., it has been met with universal acceptance. Currently, the whole planet has its Earth overshoot day in early August (meaning we would need about 1.8 planets), with some nations having it before March. However, for example, India as the most populous country, does not overshoot its resources (as yet) and naturally will attempt to have a similar lifestyle as developed countries.

As we have transgressed some of the planetary boundaries already, specific dates or events may have prompted or accelerated this problem. To this end, Steffens et al. in 2020 [16] compiled the temporary evolution of several socio-economic trends (sources, e.g., primary energy use, water use, etc.) and several of Earth system's trends (sinks, e.g., carbon dioxide, nitrogen to coastal zones, etc.) from 1750 to 2010. They identified a transition period around 1950, after which these values all increased sharply. A comparison of these unified trends to the evolution of worldwide gross domestic product (GDP) revealed that GDP also increased sharply at around 1950. The authors went on to suggest that around 1950, most governments, irrespective of political system, had decided to use the increase in GDP as their governing principle. And in an unlimited system without boundaries, this appears to make sense. Any political system may be incomplete to a certain degree and unjust to some of the nation's citizens. However, if you just stuff more and more goods into a system, you may provide hope and alleviate injustices. The problem, of course, arises at the point where the system contemplated, our planet Earth in our case, is finite and has limited planetary boundaries.

The climate crisis

As scientists, we have been trained to contemplate the complete picture in its complexity and its interrelationships. In communicating to the general public, though, an introduction through the topic of the climate crisis is readily understood. Therefore, we provide the current status in very brief terms for reference. Note that confusion may arise as some publications consider CO_2 emissions, and some consider the integrated effect of greenhouse gas emissions in terms of an equivalent CO_2 emission. The difference currently is about 75% meaning that CO_2 emissions provide about 75% of the total greenhouse gas effect to global warming.

Sometimes, opponents of the truth argue that the atmospheric content of CO_2 has been fluctuating all the time. This is true, and there have been well documented reasons for it. In fact, if we plot the CO_2 content of the atmosphere over the last 800,000 years [17], we observe somewhat periodic fluctuations of an amplitude of about 80 to 100 ppm, but not transgressing a line of 320 ppm in total (Fig. 2a). If we consider the last 60 years [18] we find a continuous increase with seasonal fluctuations to now more than 420 ppm (Fig. 2b).

Scientists have followed the correlation between atmospheric content of carbon dioxide and global temperature increase over many decades. The Intergovernmental Panel on Climate Change (IPCC) has provided various predictions based on different scenarios and has had the opportunity to interrogate its own predictions with ensuing evolution of temperature for a long time. In Fig. 3, predictions for different radiative forcing are provided up to the year 2100 [19]. Note that radiative forcing, a term introduced by the IPCC, is a quantity to assess various mechanisms with their impact on Earth's radiation balance. As the spread is quite wide, this may be contrasted with predictions by ExxonMobil [20]. While the expected increase in temperature by the year 2050 is about 2.1 °C, the predictions for 2100 lie mostly between 2.7 and 3.9 °C. Note that this is an average temperature, while the chances for big environmental catastrophes depend on weather extremes, whose likelihood has increased tremendously [19].

Climate tipping points [21] add substantial risk to our earth system. To avoid confusion, we refer to the definition provided by McKay et al. in 2022 [22]: "*Tipping points occur when change in part of the climate system becomes (i) self-perpetuating beyond (ii) a warming threshold as a result of asymmetry in the relevant feedbacks, leading to (iii) substantial and widespread Earth system impacts*". They are typically irreversible, occur on a scale of, e.g., 1000 km in extension, and unfold on a timescale of thousands of years, with

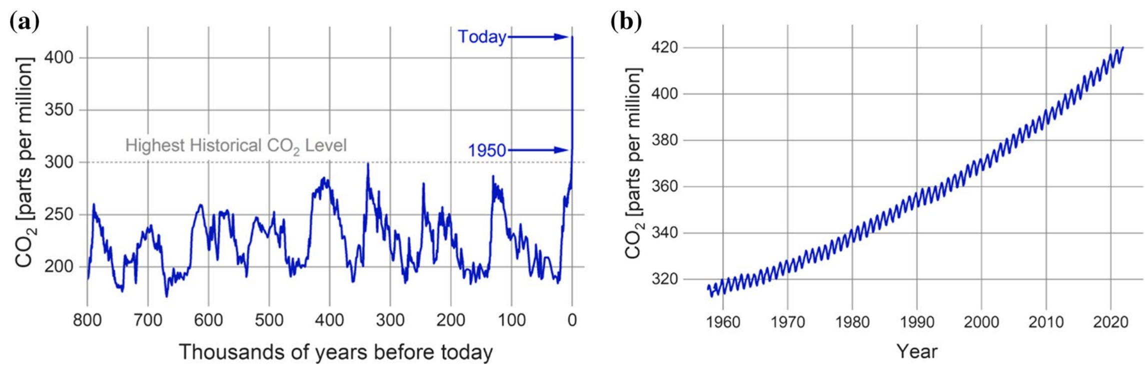

Figure 2 Atmospheric CO_2 content in parts per million **a** over the past 800,000 years [17] and **b** since 1958 [18]. *Note*: The data used for Fig. 2a stems from ice drill cores taken from the EPICA Dome C location in Antarctica. While providing a long-ranging historical overview, this dataset is also the most often cited of the available ice core data records. For the time from the 1950's to today, the Keeling curve, provided in Fig. 2b, was added. This curve showcases the data of the longest uninterrupted measurement of the atmosphere's CO_2 concentration from the Mauna Loa Observatory in Hawaii and was an early piece of evidence for anthropogenic climate change.

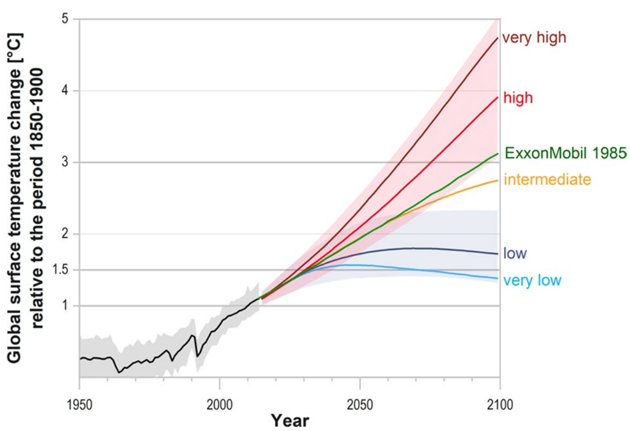

Figure 3 Greenhouse gas emission scenarios. Dark red, red, yellow, blue, and light blue show different levels of emissions from scenarios of the IPCC 2022 [19], green provides an internal prognosis of ExxonMobil from 1985 [20]. *Note*: Fig. 3 was made with predictions from Shared Socioeconomic Pathways (SSP) scenarios of the IPCC Assessment Report 6. These reports review the literature on the current status of climate change and are peer reviewed by thousands of international scientists, and discussed by government officials, before being published. To put these predictions into an industry perspective, an internal prediction of ExxonMobil from 1985, that was only recently was made public, was added to the graph.

more abrupt timescales also possible. An important feature of tipping elements is that they are self-perpetuating. This means even if the origin for the change of the system ceases, the change continues nevertheless. Ice collapse of the Greenland ice sheet is considered to lead to an increase in sea level of 7 m, while part of the East Antarctica ice sheet would add another 3 m if collapsing [21]. In general, climate tipping points are considered for the cryosphere (frozen water in the earth system), the biosphere, and the ocean–atmosphere circulation. Several estimates for global warming tipping lie at about 2 °C. Various regional tipping points also exist, with the glaciers in Europe expected to disappear with 2 °C global warming and the glaciers in the high mountains in Asia to persist somewhat longer but with large social impact on populations benefitting from the freshwater stemming from melting glaciers in the summer [21].

International political organizations

In order to inform the nations about the climate change caused by human activities, the IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environmental Program and endorsed by the United Nations in the same year. Its bureau sourced experts from nominations by participating governments and observer organizations. Since its creation, the IPCC has provided six assessment reports. These again are rooted in a summary of scientific publications which extracts the required information for governments in short form and detailed long version. In addition, the IPCC formulates response options.

Annual conferences by the United Nations on climate change have been held since 1995. They are held in the framework of the United Nations Framework on Climate Change and assess the progress in dealing with the climate change. The Kyoto protocol from 1997 is well known, and the Paris agreement from 2015 is a legally binding international treaty on climate change, which was adopted by 198 nations. At the 27th UN conference in Glasgow in 2021, general secretary Guterres stated, that today, hardly anyone of these nations is on target.

Past international scientific achievements

While the results of international political collaborations to combat the sustainability crisis may seem discouraging, we do not wish to move to the role of the scientist without highlighting past scientific achievements in dealing with global threats.

Rachel Carson has been generally credited as one of the initiators of the global environmental movement. She was a trained biologist but had become a full-time nature writer in the 1950s. Her style was credited with being both scientific as well as poetic. Then she turned her attention to conservation and published the book "Silent Spring" [7] in 1962. It described her waking up one morning and finding that the birds have gone. At that time, insecticides like DDT in the US were sprayed from airplanes raining down on garden patches, cow pastures, rivers, and roads alike. Rachel Carson picked up the dead insects and the birds from her environment.

Rachel Carson's book, the resistance of the chemical industry, paired with her being an American established writer, her presence in the *The New Yorker* and the editorial in *The New York Times*, allowed her to have a huge impact: In 1968, Hungary was the first country to ban DDT; the US founded the environmental protection agency in 1970 and banned DDT in 1972.

In a review paper from 1999 [23], the depletion of the ozone layer was described *"as one of the major global scientific and environmental issues of the twentieth century"*. The depletion of ozone above the Antarctic meant a reduced absorption of UV light and an increased risk of skin cancer in particular in Australia. Already in 1985 [24], the seasonal character, related to very low temperatures, of the ozone depletion had been related to a chemical reaction involving chlorine monoxide (ClO). An airborne chemical quantification of chemical species across the ozone hole had then, in 1987, conclusively proven that a very large quantity of chlorine monoxide coincided with the spatial extent of the depleted ozone layer. Still the same year, the United Nations Environmental Program passed a treaty to reduce chlorofluorocarbons. As a result, their production had fallen by a factor of ten in 2000 [25], and the ozone hole had started to close.

Severe acute respiratory syndrome coronavirus (SARS-CoV-2) was the first acute pandemic in the twenty-first century. It had followed previous pandemics (MERS-CoV and SARS-CoV), which had allowed us to take a glimpse into the dangers which we may be facing. Although scientists had sounded warnings after the earlier pandemics, the world proved mostly caught by surprise. Yet, the extremely fast development of vaccines, excluding missing out on some earlier pre-trial steps, limited the already huge impact on societies worldwide [26].

It is helpful to draw parallels between the experience of the COVID-19 pandemic and the sustainability threats we face. The pandemic crisis shares many similarities with sustainability challenges. One crucial lesson from the pandemic was the complexity of effectively communicating scientific information to the general population, and the inherent uncertainty in predicting outcomes. While the rapid development of new vaccines during the pandemic was impressive from a technical standpoint, the low acceptance rates of vaccines in many countries proved disappointing. In several countries with advanced health care system, the overall vaccination rate barely reached two-thirds, and confusion and uncertainty were prevalent sentiments. Even more concerning was the widespread generation of misinformation about government actions and scientific recommendations. This misinformation found acceptance among large segments of the population, and a disturbing number of people refused to comply with recommended guidelines. Furthermore, there was a lack of global alignment in efforts to combat the pandemic.

The pandemic experience made it abundantly clear that technological solutions alone were insufficient to manage the crisis. Effective communication and social efforts were equally, if not more, critical. Similarly, skepticism and misinformation surround climate threats and sustainability crisis, particularly among certain segments of the population. This skepticism may intensify as we are forced to implement unpopular measures. Just like pandemics, sustainability crises are global issues that can only be effectively addressed through the collective efforts of all nations. Unfortunately, it seems unlikely that present and future geopolitical rivalries among major powers will be easily overcome to efficiently confront climate and sustainability crises [27].

Given these challenging circumstances, it becomes even more urgent for scientists and scientific societies, encompassing both natural and social sciences, to act on a global scale. They must collaborate even when major powers are at odds, bridge ideological divides and conflicting national interests, combat misinformation, and propose viable solutions. This is undoubtedly a formidable task, but a necessary one.

The role of international scientific networks

The power of science across disciplines and nations

The sustainability crisis concerns all life on Earth in all countries and oceans. It requires strong, worldwide action. The nations feature widely different stages of development, attempt to enhance their economy, or at least do not expect to shrink it. However, their historical contribution to environmental damage to our planet widely differs. At the same time, international political networks suffer from several parallel crises and an enhanced nationalistic preference.

Therefore, a second international network for communication is necessitated. International sciences, in their full-scale interdisciplinarity, offer a tool for this demand in dissemination. Further, the sustainability crisis consists of several parallel problems and is therefore systemic and integrative in nature. Also, changes in one aspect may affect another field (Fig. 1 and Table 1), and improvement frequently leads to rebound, making the situation worse instead of better. Scientists across the disciplines and nations are therefore called upon to engage in systemic understanding of the sustainability crisis to communicate to the general public across the nations. We thus could provide more guidance to the political decision makers, help citizens better understand difficult choices lying ahead, and enhance the understanding between the countries with their various national interests.

Already the simple issue of exponential growth is deeply disturbing. Consider that many nations would love to have economic growth of, e.g., 6% annually. Then perform a simple computation and arrive at the result that in only 12 years, the use of resources and sinks will double. Hence, we need to consider the dynamics of the problem and the usage time of key infrastructure of, e.g., power plants of about 30 years, to realize that humankind needs to act 30 years before it is much too late. These are timescales politicians are not familiar with.

Academies

In many countries, the key role of scientific academies is to advise governments. Members of scientific academies have gone through a rigorous selection process and are highly committed individuals. The union of German academies, encompassing the German Academy of Science and Technology (acatech), the German National Academy of Sciences (Leopoldina), and the Union of the German Academy of Sciences, published an assessment in February 2023 titled: "How to get Germany emission-free? Options for technology change, reduction in consumption and carbon management" [28]. They structured their statement into five core messages:

1. Climate neutrality cannot be achieved without comprehensive societal and political realignment.
2. Climate goals are hardly achievable without changes in demand.
3. Technological transformation must be drastically accelerated.
4. A triad of climate-neutral processes, circular economy, and material efficiency is necessitated.
5. CO_2-capture is required, but cannot replace reduction in CO_2-emissions.

Along the same lines, the Royal Society, in collaboration with other academies, has issued a call to governments to act on the climate crisis as quickly as possible. It also issued a set of briefings to outline how the range of challenges can be met [29].

Scientific societies

There are numerous examples where scientific societies utilized their insight to communicate with political institutions and indeed, obtained fruitful actions by respective governments. To take just one example: The worldwide largest physical society, the German Physical Society (DPG), joined forces with the German

Meteorological Society (DMG) in 1987 and sounded a clear and pressing warning to the society and the political stakeholders [30] and television broadcastings. In effect, this led to a German parliamentary commission, which, in 1990, demanded a reduction of carbon dioxide emissions for the European Union by 2005.

The media were keen to pick this up, with the weekly magazine "Der Spiegel" visualizing the increased sea level in a rather drastic form, with the Cologne cathedral standing in a sea of water without any shore visible. This medial extortion of the climate crisis was often noted as dulling the senses of the public with the common response to warning signals: "I know, I have seen the Cologne Cathedral submerged in water a long time ago!".

The sciences and their societies therefore have an obvious role to play in mitigating the crisis. This does not only include natural and engineering sciences [31] but very strongly also human sciences, which then includes the biological, psychological, philosophical, and cultural ways of life. In particular, the effort also needs to include sociology, law, and economics. These can reach out to the public and their membership through webinars on sustainability, featuring lectures both from their own members as well as from climatologists, biologists, agronomists, or other most exposed scientific disciplines to the sustainability gap. This can include sustainability into dedicated sessions at conferences, not only limiting the topics to narrow aspects of their own field but also presenting the wider, systemic picture. Nevertheless, scientific societies are also called upon to reduce the ecological footprint of all activities of the society to set truthful and credible examples in order to communicate with the general public in an efficient manner.

This paper has been submitted to one of the most general and widespread Journals in Materials Science. Materials Science really here is just one of many scientific disciplines. The field has particular involvement with the development of new materials for energy conversion, energy transport and energy storage, thermal insulation, and many more.

However, our responsibility as materials scientists has to go much further in the broad-scale dissemination of this crisis in all of its scientific and societal ramifications. Hence, we purposely do not discuss our technological contributions as this has been done in many other publications. However, there is one example, where Materials Science is attempting to make an additional contribution. This lies in the recent move to establish an "alliance of societies for a sustainable future" based on four international Materials Science Societies. This alliance is geared toward providing a framework for scientific societies to jointly work in disseminating our needs and options for a livable planet.

Universities and National laboratories

A good example of an encompassing policy on sustainability is provided by a document of the EPFL [32], which was published in early 2023 and sets ambitious quantitative goals for reduction of greenhouse gas emissions for 2030.

Universities need to consider the following aspects:

a) Teaching, ideally as universal University-wide courses on sustainability and courses allowing the students to understand systemic, integrative problems with their interrelationships and options for rebounds.
b) Infrastructure and operations, with the need to cut waste and become energetically more efficient. Large commutes must be reflected, and public transport be made more efficient to reduce environmental impact.
c) Naturally, research is needed into all aspects of sustainability, in particular with respect to the planetary boundaries and their interdependencies.
d) Travel and participation at conferences need to be critically reviewed. It appears that senior, established researchers have given up on self-determined conference travel. Rather, the chorus can be heard in many hallways of scientific institutions: "I have been invited, I have to go (even if one has long stopped working in a given field and rather should expose oneself to new fields)." At the same time, the requirement for younger researchers to build networks through in-person participation at international conferences needs to be accepted.

Naturally, national laboratories and scientific institutions, in general, face the same challenges. CNRS[1] Management, for example, identified four key areas impacting carbon dioxide emissions: purchase and

[1] Centre national de la recherche scientifique—the National Research Institution in France is the second largest in Europe, following its equivalent in Germany.

disposal, computer networks, mobility, and energy [33]. They found that the largest contribution to emissions stems from purchase. This resulted in a key goal to consider purchases much more from the standpoint of sustainability. Simply put: We need to spend less and more wisely. And that requires both individual effort and systemic change.

Change agents

In the end, change is driven by individuals. These need to communicate in their respective circles and need to educate people, and need to find multiplicators. They need to form new or empower existing networks, which need to overlap and reach out across national borders and disciplines.

It may be fitting at the end of this viewpoint to reflect the CNRS report, where it addresses the individual researcher: *1. 11,258 scientists from 153 countries recalled the 'moral duty' of scientists "to give clear warning to humanity of any catastrophic threat and speak truth to power"; 2. "…it is the collective responsibility of research to act as a watchdog…. Scientists thus have a crucial role to play in alerting others to risks. Scientists must use their discernment in identifying miracle solutions and false promises (such as implementation of geo-engineering techniques)"* [34].

Others

The movement "Fridays for future" created by Greta Thunberg received tremendous worldwide support from pupils from primary and secondary schools. Therefore, schools will have an important role to play in teaching and discussing the sustainability gap. Similarly, museums offer many opportunities for dissemination and reflection. National laboratories now already partake, dependent on their focus mission, in the working groups of the IPCC and are involved in manyfold activities. We are sure we have not named all stakeholders related to science, but there are manyfold contributions to be made by the scientific disciplines, its teachers, and scholars.

Conclusions

We know it, and we have known it for a considerable amount of time. Yet, the truth remains inconvenient. The option of a convenient path with exciting discussions on technological advancements and casual talks about the recent environmental damage in other regions of the earth has faded away at an alarming pace. In reviewing salient knowledge on the sustainability crisis with some of its facets and sketching past mistakes and achievements, we need to stand together as scientists: *For a global problem of this scale, the sustainability effort must become an international and joint endeavor of all nations and humankind.* Encouraged by past achievements in our professions, we are required to communicate on various levels and provide solutions not only on the technological front but even more so by the humanistic and social sciences, including those in the fields of sociology, psychology, philosophy, economy, law, and many others.

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