„Making it a Success!”

RESEARCHERS OF HELMHOLTZ ASSOCIATION OUTLINE THE ROADMAP TO A CLIMATE-NEUTRAL GERMANY

BY DR. STEFAN FUCHS
TRANSLATION: FACHÜBERSETZUNGEN HUNGER/ALTMANN GBR

Under the title Net-Zero CO_2 Germany – A Retrospective From the Year 2050, 37 authors from all research fields of the Helmholtz Association dared to take a fictitious look at the year 2050, a year marked by the successful climate turnaround. The text emanates from the work of the Net-Zero-2050 cluster that is part of the Helmholtz Climate Initiative. Included is a scientific estimation of the potential of the technologies used to eliminate CO_2 from the atmosphere, which are factored into the balance of negative greenhouse gas emissions by the Intergovernmental Panel on Climate Change (IPCC).

The unusual back-casting perspective that traces back the path to success from the finish line is a concept by Professor Roland Dittmeyer, Head of the Institute for Micro Process Engineering (IMVT) of KIT, who co-authored the article. “The goal to fully abandon the fossil energy carriers appears to be such a huge effort that many indeed become discouraged. If, in contrast, the story is told from a successful ending, there is quite some encouragement to it,” says Dittmeyer. For co-author Professor Eva Schill of the Institute for Nuclear Waste Disposal (INE) of KIT, it is easier to retrospectively view the transdisciplinary interaction of the many mosaic pieces that will contribute to success. “The multitude of technology pathways visible today – not all of them will prove to be a success – makes it difficult to discuss such a complex subject matter in a concise text. This is why we chose the other way around. The IPCC highlights the goals we should have reached in 2050. This retrospective approach allows us to consolidate all requirements under one roof in an interdisciplinary manner,” Schill explains.

The Winning Formula: Renewable Energies

Avoiding, reducing, and removing CO_2 emissions are the three basic strategies

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KIT researchers work on the production of synthetic fuels and energy carriers from carbon dioxide and renewable electrical energy

Am KIT arbeiten Forschende an der Herstellung synthetischer Kraftstoffe und Energieträger aus Kohlendioxid und erneuerbarer elektrischer Energie

FOTOS: AMADEUS BRAMSIEPE

whose respective contributions to the Net-Zero goal that were compared in the text. Among these three, avoiding greenhouse gas emissions shows by far the greatest potential for reduction. With a reduction of more than 95% of the CO_2 emissions, the transition to renewable energy sources makes a major contribution towards reaching this goal. The two other strategies depend on the availability of green electricity, which would require the expansion of photovoltaic and wind power plants. The capacities must increase from their current total (about 120 GW) by 10 GW annually to reach well over 600 GW by the middle of the century. Thus, future energy generation will be widely distributed over the entire land. This, however, will aggravate conflicts of usage. The scientists therefore favor adapted land and technology management. "Besides increasing the efficiency of individual technologies, we must look at areas that have little potential for food production or allow for co-usage," says Eva Schill. "We observe first concepts towards multi-use of land for farming, harvesting solar energy in form of electricity and heat as well as storing the latter in the underground and at the same time. But moreover we must put forward technologies that need little space such as geothermal energy." Roland Dittmeyer identifies dual usage potential on sealed surfaces. "I prefer energy-generating facilities on buildings and car parks, even though they are more expensive than on open space," the researcher emphasizes.

No Way without Chemical Energy Sources

The natural fluctuation of wind and solar energy requires an expansion of storage technologies. In the success scenario, the conversion of green electricity to methane, methanol, or hydrogen by Power-to-X technologies plays a crucial role for mid- and long-term storage of the energy – although more than half of the green power is lost on the detour via so-called e-hydrocarbons. This conversion, however, allows coupling the energy, heating, and traffic sectors. "Part of the energy can be stored in existing natural-gas storage facilities. Due to the specific physical properties of green hydrogen, it will, however, be necessary to build an added, dedicated infrastructure," Dittmeyer believes.

Even in 2050, Germany will not be able to do without energy imports. In southern countries, solar electricity can be harvested at lower cost. While nearly 100% of that energy would have to be imported today, a substantial part will come from domestic production in 2050. "If we store surplus energy here at different places using intermediate carriers, we can improve our resilience and can keep going for a longer time in case of hardships," says Dittmeyer.

A Problem Case: Agriculture

Agriculture counts among the major problem areas on the road towards the Net-Zero goal for greenhouse gases. An important prerequisite for success lies in reform of European agricultural policy. However, even satellite-based precision fertilization, special techniques of soil cultivation, and an increase in the CO_2 storage capacity of soils and plants will not be sufficient to reduce the emission of greenhouse gases to zero, especially as methane is emitted here in addition to CO_2. Steel production, in contrast, offers the possibility of a large-scale CO_2 reduction by using electricity-based direct reduction or by conversion of the production process to hydrogen technology. "Ammonia production could also be fully decarbonized by the use of green hydrogen," emphasizes Dominik Heß of the Institute for Micro Process Engineering (IMVT) of KIT, also a co-author of the article.

Reverse Combustion

The authors estimate that, after leveraging all available avoidance and reduction strategies, Germany would still produce an annual base amount of 60 million tons of CO_2, especially from farming and the processing of residential waste. The rest can only be eliminated by applying strategies that actively remove the greenhouse gas from the atmosphere. "This is basically the reversal of what we have done since the beginning of indus-

FOTO: MARKUS BREIG

Professor Roland Dittmeyer, head of the KIT Institute of Micro Process Engineering (IMVT) (left), and professor Eva Schill, KIT Institute for Nuclear Waste Disposal (INE) (bottom)

Professor Roland Dittmeyer, Leiter des Instituts für Mikroverfahrenstechnik (IMVT) des KIT (links), und Professorin Eva Schill, Institut für Nukleare Entsorgung (INE) des KIT (unten)

FOTO: AMADEUS BRAMSIEPE

„So wird es gelingen!"

Forschende der Helmholtz-Gemeinschaft beschreiben den Weg zu einem klimaneutralen Deutschland

Unter dem Titel „Net-Zero CO_2 Germany – A Retrospect From the Year 2050" haben 37 Forschende der Helmholtz-Gemeinschaft den Blick in ein Jahr 2050 gewagt, in dem die Klimawende gelungen ist. Der Text ist aus den Arbeiten des Net-Zero-2050-Clusters der Helmholtz-Klima-Initiative hervorgegangen. Das Konzept zu der ungewöhnlichen Perspektive von der erreichten Zielmarke zurück auf den Weg zum Erfolg stammt von Co-Autor Professor Roland Dittmeyer, Leiter des Instituts für Mikroverfahrenstechnik (IMVT) des KIT. „Das Ziel der vollständigen Abkehr von fossilen Energieträgern stellt eine derart gewaltige Anstrengung dar, dass viele resignieren. Wenn man die Geschichte dagegen von einem Erfolg ausgehend erzählt, hat das etwas Ermutigendes", sagt Dittmeyer. Für Co-Autorin Professorin Eva Schill vom Institut für Nukleare Entsorgung (INE) des KIT erleichtert die Retrospektive die Zusammenschau der vielen Mosaikbausteine, die den Erfolg möglich machen. „Der IPCC zeigt uns, welche Ziele wir in 2050 erreicht haben müssen. Der retrospektive Ansatz erlaubt es, alle Vorgaben interdisziplinär unter ein Dach zu bringen", erklärt Schill.

Nach Erkenntnis der Forschenden ermöglicht ein Umstieg auf erneuerbare Energiequellen eine CO_2-Reduktion von über 95 Prozent. Für die Klimawende ist daher ein Ausbau von Fotovoltaik und Windkraft notwendig. Da Energie so zukünftig in der Fläche gewonnen wird, entstehen jedoch Nutzungskonflikte. „Wir müssen überlegen, welche Flächen sind ungenutzt, auf welchen Flächen ist eine Ko-Nutzung möglich?", sagt Eva Schill. Dazu gehört etwa eine Doppelnutzung von landwirtschaftlichen Flächen, Gebäuden oder Parkplätzen und Fotovoltaikanlagen. Die natürliche Fluktuation von Wind- und Solarenergie macht einen Ausbau der Speichertechnologien notwendig. Für eine mittel- und langfristige Speicherung der Energie spielt im Erfolgsszenario die Umwandlung des grünen Stroms durch Power-to-X-Technologien in Methan, Methanol oder Wasserstoff eine entscheidende Rolle.

Die Landwirtschaft zählt zu den größten Problembereichen auf dem Weg zu einem Netto-Null bei den Treibhausgasen. Eine wichtige Voraussetzung für den Erfolg ist deshalb die Reform der europäischen Landwirtschaftspolitik. Aber auch in der Industrie muss der CO_2-Ausstoß weitgehend reduziert werden. Um den nicht vermeidbaren CO_2-Emissionen entgegenzuwirken, sind Strategien notwendig, die das Klimagas aktiv aus der Atmosphäre entfernen. Dafür kommen sogenannte Carbon Dioxide Removal-Verfahren (CDR) und Direct Air Capture-Technologien (DAC) zum Einsatz. Das aus der Luft gewonnene CO_2 kann außerdem dazu dienen, chemische Grundstoffe sowie klimaneutrale Treibstoffe herzustellen. ■

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In order to be able to store CO_2 underground Carbon Dioxide Removal (CDR) processes are necessary. They can be combined with the energetic utilization of biomass

Um CO_2 im Untergrund speichern zu können, sind sogenannte Carbon Dioxide Removal-Verfahren (CDR) notwendig. Sie können mit der energetischen Verwertung von Biomasse verbunden werden

FOTO: PATRICK LANGER

trialization," states Eva Schill. "By burning fossil energy carriers, we released into the atmosphere CO_2 that was previously bound in the deep underground. Now, we need to refilter it and bring it back into the deep underground in the form of a chemical bond that is as stable as possible."

Natural ways for eliminating CO_2 from the atmosphere can complement technological methods. This includes re-foresting, cultivation of seaweed beds, and peatland rewetting. Eva Schill, however, raises the question of permanence. "The climate change can impair the storage capacity of the natural CO_2 sinks in the biosphere. As a geologist, I prefer the deep underground," the researcher says. "It offers the possibility for permanent fixation, regardless of any biological cycles."

To store CO_2 in the subsurface, so-called carbon dioxide removal processes (CDR) are needed. These can be linked with the energetic use of biomass: CO_2 stored in plants during their growth process is filtered out of the exhaust gas during the combustion of biomass and injected, for example, into former gas or natural-gas reservoirs. In a chemically reactive subsurface, such as in Hellisheiði (Iceland), the greenhouse gas at once reacts with the rock, forming carbonate minerals. Since the production of biomass is accompanied by land consumption, Direct Air Capture technologies (DAC) also are needed. "This process consists of capturing the CO_2 from the air in a technical facility, requiring much less space for the same amount of captured CO_2," says Roland Dittmeyer. He adds, "The broader public does not yet realize that the chemical raw materials, e.g., to produce plastics, which are nowadays based on fossil oil, will require a different carbon source in the future. This can be neither oil nor gas nor coal. Moreover, even biomass is only available in limited quantities for this purpose. This means that the CO_2 captured from the air using CDR is indispensable. And it is also needed for the production of climate-neutral fuels in transport, such as sea and air traffic, which can hardly be electrified in the short run." ■

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ANZEIGE

UND SONST?KIT

ULTRAFEINSTAUB KÖNNTE WETTEREXTREME VERURSACHEN

GLOBALER ANSTIEG VON ULTRAFEINEN PARTIKELN AUS ABGASEN FOSSILER BRENNSTOFFE

ULTRAFINE DUST MIGHT CAUSE WEATHER EXTREMES

GLOBAL INCREASE OF ULTRAFINE PARTICLES FROM EXHAUST GASES OF FOSSIL FUELS

VON MARTIN HEIDELBERGER // TRANSLATION: FACHÜBERSETZUNGEN HUNGER/ALTMANN GBR // FOTO: BODENBENDER LUFTBILDAGENTUR

Ob Starkregen oder extreme Trockenheit – weltweit nehmen Extremwetterereignisse zu. „Bislang wurde die Zunahme von Wetterextremen vor allem auf das ansteigende Kohlendioxid und die höhere Wasserdampfkapazität der sich erwärmenden Atmosphäre zurückgeführt", sagt Dr. Wolfgang Junkermann vom Institut für Meteorologie und Klimaforschung – Atmosphärische Umweltforschung (IMK-IFU), dem Campus Alpin des KIT in Garmisch-Partenkirchen. Da Kohlendioxid aber räumlich relativ gleichmäßig verteilt sei, ließe sich damit die Variabilität in der Verteilung und im Auftreten von Extremwetterereignissen nicht befriedigend erklären. Gemeinsam mit Professor Jorg Hacker vom unabhängigen Forschungsinstitut Airborne Research Australia (ARA) argumentiert Junkermann, dass ultrafeine Partikel mit bis zu 100 Nanometern aus der Verbrennung von fossilen Kraftstoffen signifikant zu Extremwetterereignissen beitragen, indem sie als Kondensationskerne regional und kurzfristig auf die Wolkenphysik einwirken. „Mit Modellen für die Wolkenbildung können wir zeigen, dass sich durch die Zunahme von ultrafeinen Partikeln mehr und kleinere Tropfen bilden", erklärt Junkermann. „Dadurch verweilt Wasser viel länger in der Atmosphäre. Der Regen wird zunächst unterdrückt und es entsteht ein zusätzliches Energiereservoir in der mittleren Troposphäre, das extreme Niederschläge begünstigt. Das kann dann hunderte Kilometer entfernt passieren. Eine heterogene Verteilung der Nanopartikel-Verschmutzung könnte beitragen, die regionalen Unterschiede bei Extremwetterereignissen zu erklären." Beim Vergleich von Daten zur Menge und Verteilung von Ultrafeinstaub in der Erdatmosphäre sowie zu Veränderungen im Wasserkreislauf fanden die Forscher heraus, dass in vielen Gebieten ein Anstieg der Partikelanzahlen mit regional veränderten Niederschlagsmustern korreliert. Möglich wurde der Befund durch umfangreiche Messreihen mit Kleinflugzeugen, mit denen die Forscher über 20 Jahre den wohl größten Datensatz dieser Art zusammengetragen haben. Mit den Daten belegen die Forscher einen extremen Anstieg der Partikelemissionen seit den 1970er-Jahren. „Dies konnten wir auf Kraftwerke, Raffinerien oder den Schifffahrtsverkehr zurückführen, oft und besonders auch auf Großfeuerungsanlagen mit neuester Abgastechnologie", sagt Junkermann. ■

Whether it be heavy rainfall or extreme drought, the frequency of extreme weather events is increasing worldwide. "So far, climate researchers have attributed these changes to a growing carbon dioxide concentration and the higher water vapor capacity of a warmer atmosphere," says Dr. Wolfgang Junkermann from the Atmospheric Environmental Research Division of KIT's Institute of Meteorology and Climate Research (IMK-IFU) at KIT's Campus Alpine in Garmisch-Partenkirchen. However, as the spatial distribution of carbon dioxide is homogeneous, it does not sufficiently explain why particular regions are affected more severely by extreme weather events than others. Together with climate researcher Professor Jörg Hacker from the independent Airborne Research Australia (ARA) research institute, Junkermann points out that ultrafine particles up to 100 nanometers in size produced by the combustion of fossil fuels significantly contribute to extreme weather events. That is because they function as condensation nuclei and have a regional, short-term impact on cloud physics. "Using conventional cloud formation models, we can show that the increase in ultrafine particles results in the formation of more and smaller droplets," Junkermann explains. "As a result, water stays in the atmosphere much longer, rain is initially suppressed, and an additional energy reservoir develops in the middle troposphere, which promotes extreme precipitation that may then hit an area hundreds of kilometers away. A heterogeneous distribution of nanoparticle pollution might explain the considerable regional differences of extreme weather events." When comparing data on the amount and distribution of ultrafine dust in the Earth's atmosphere and on changes of the hydrological cycle, the researchers found that, in many regions of the Earth, an increase in particle numbers correlates with a change of precipitation patterns in certain areas. This finding is based on extensive measurements made with small airplanes over a period of 20 years that generated probably the largest dataset in this field. This dataset confirms an extreme increase in particle emissions since the 1970s. "We were able to attribute these extreme concentrations to power plants, refineries, and ship traffic, – and especially large incineration plants with the latest exhaust gas technology that were often identified as sources of such emissions," Junkermann says. ■