APS News

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The daunting physics of carbon removal

A new APS report outlines the challenges of scrubbing carbon dioxide from the atmosphere.

By Liz Boatman

Climeworks' Mammoth plant in Iceland, which began operations in May 2024. The plant removes carbon dioxide with direct air capture — one of the methods examined in APS' latest report. Credit: Climeworks

Anthropologists believe our ancestors first used fire as a tool nearly two million years ago. Eventually, fire became a necessity for cooking and warmth. Then, 4,000 years ago, dwellers in modern-day northern China discovered a black rock that burned better than wood: coal.

Today, we mine and consume an estimated 8.8 billion metric tons (tonnes) of coal every year, among other fossil fuels, freeing into Earth's atmosphere billions of tonnes of carbon that had been locked away in Earth's crust for hundreds of millions of years. That carbon dioxide, we now know, is blanketing our planet — trapping heat, supercharging hurricanes and heat waves, and melting vast expanses of sea ice and glaciers.

As countries race to drive their annual greenhouse gas emissions to net zero by 2050, some are contemplating a different question: What can we do about the 1.5 trillion tonnes of carbon dioxide we've already added to our atmosphere?

On Jan. 27, APS released a new report, "Atmospheric Carbon Dioxide Removal: A Physical Science Perspective," that aims to answer this question. The four authors of the report — which was commissioned by the APS Panel on Public Affairs — are Washington Taylor of the Massachusetts Institute of Technology, Jonathan Wurtele of the University of California, Berkeley, APS Past President Bob Rosner of the University of Chicago, and APS President-elect Brad Marston of Brown University.

The report summarizes the current state of available carbon dioxide removal (CDR) technologies and outlines recommendations for policymakers. Above all, the report emphasizes that in most cases, cutting current carbon emissions is easier and less costly than large-scale, engineered carbon dioxide removal efforts may ever be.

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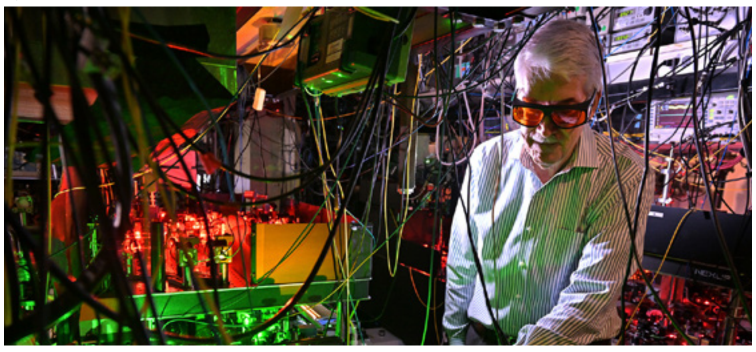
John Doyle sees opportunities for science and APS in the year ahead

In an interview, the 2025 APS president shares his academic journey, achievements from the field of atomic physics, and his vision for APS' future.

By Erica K. Brockmeier



John Doyle in Lyman Lab at Harvard. At APS, "our policy is truth, and we tell the truth about science," Doyle says. Credit: Josh Reynolds

Between running an ultra-cold molecular research lab, co-leading Harvard University's Quantum Science and Engineering Initiative, and now serving as the 2025 APS president, John Doyle has had a lot on his plate.

But Doyle stays motivated thanks to "the community, the science, and the incredible scientists that are working every day to pursue this exciting work," he said. "If there's something I can do to support that, then I feel invigorated and energized."

Doyle, also the former chair of the APS Topical Group on Precision Measurement and Fundamental Constants, brings a wealth of expertise to the APS Board. He holds a bachelor's degree in electrical engineering from the Massachusetts Institute of Technology, where his experience working in an atomic and condensed matter physics lab as an undergraduate motivated him

John Doyle continued on page 4

Join our campaign to protect science

A letter from APS President John Doyle and CEO Jon Bagger.

Like many of you, we are deeply concerned by recent executive actions. We share your frustration and dismay. The American science and technology enterprise has been targeted. Colleagues have lost their jobs. Students face an uncertain future. Collaborators, mentors, and friends are in pain. The stakes are high, and we know how heavy this moment feels. But history teaches us that, together, we are powerful. APS is mobilizing its resources to support the physics community, and we invite you to join this effort. As a first step in a multifaceted campaign, we are launching a nationwide advocacy initiative, and we need your help.

Draconian cuts to agency budgets, including NSF, NIST, and DOE, will do immediate and long-term damage to our community — and science more broadly — by creating chaos, canceling projects, and upending careers. The effects will be disastrous: physics research leading to paradigm-shifting discoveries left unfunded and unpursued, a domestic STEM workforce unable to meet the demands of the global economy, a decline in U.S. innovation, and thousands of would-be physicists who never even have the opportunity to pursue our field. This is a future we cannot accept.

Please join our campaign to make Congress understand why federal support for science is critical to America and Americans.

Right now, we need you to share your experiences showcasing the transformative positive impact of NSF, NIST, DOE, NASA, and DOD-

APS Campaign continued on page 6

The crisis of displaced scientists — and how you can help

Around the world, hundreds or thousands of scientists are forced from their homes each year. Getting to safety is only half the battle.

By Kendra Redmond

When Encieh Erfani left home in August of 2022, she packed light. She had a fellowship to visit a research institute in Mexico for a few months, then she'd return to the Institute for Advanced Studies in Basic Sciences, a public research university in Iran where she was a physics professor. But then Mahsa Amini was killed.

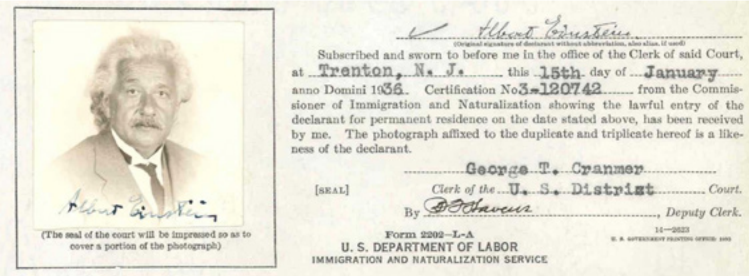
Erfani had been in Mexico for only three weeks when news broke that a young woman in Tehran was arrested and beaten by Iran's morality police for not wearing a hijab; Amini died in their custody three days later.

"It had a really profound effect on me," says Erfani, an Iranian who years earlier had chosen to stop wearing a hijab when she traveled outside of the country. "I didn't imagine that not wearing a hijab could lead to death."

Erfani recalls watching the protests — which were started by university students — on the news. "They were shouting, 'Why are our professors silent?'" The question resonated with her.

"I really asked myself, Why should I keep silent?" she says. "How much can I tolerate the situation of this regime?" She concluded that enough was enough.

Erfani wrote a short email to fellow faculty members and physics



Albert Einstein
(Original signature of declarant without abbreviation, also alias, if used)
Subscribed and sworn to before me in the office of the Clerk of said Court, at Trenton, N. J. this 15th day of January anno Domini 1936. Certification No 3-120742 from the Commissioner of Immigration and Naturalization showing the lawful entry of the declarant for permanent residence on the date stated above, has been received by me. The photograph affixed to the duplicate and triplicate hereof is a likeness of the declarant.

George T. Cranmer
[SEAL] Clerk of the U. S. District Court.
By [signature], Deputy Clerk.

Albert Einstein
(The seal of the court will be impressed so as to cover a portion of the photograph)

Form 2202–L–A
U. S. DEPARTMENT OF LABOR
IMMIGRATION AND NATURALIZATION SERVICE
14—2023

An excerpt from Albert Einstein's Declaration of Intention to become a U.S. citizen in 1936. Like Einstein, many scientists fled Nazi rule between 1933 and 1941. The scientific community supported them through organizations such as the Emergency Committee in Aid of Displaced Foreign Scholars (America) and the Society for the Protection of Science and Learning (Great Britain). Credit: US National Archives and Records Administration.

students. The last line explained that she was resigning in solidarity with the Iranian people. Fourteen hours later, a family member received a threatening call from the intelligence service asking about her, Erfani says. She knew she couldn't return, even to pick up her employment and education records. At least not right away.

"I had a hope that these protests would lead to the collapse of the regime and I would be able to come back home after a few months," she says. But it's been two years now. Were she to go back home today, Erfani anticipates that she could face, at minimum, more than 20 years in jail for her criticisms of the regime.

Her story is one of many.

Hundreds of scientists — even thousands — can be displaced from their home countries in any given year, according to Michael Martin, a national laboratory scientist and advocate for displaced scientists. According to the National Academies, an estimated 5,000 have fled Ukraine alone since 2022. Persecution, conflicts, and war are simultaneously displacing scientists from Syria, Iran, Afghanistan, Haiti, Venezuela, Palestine, Yemen, Sudan, and other areas.

"It's a constantly moving crisis," Martin says. And if you broaden the scope of the conversation to include engineers, programmers, and other STEM personnel, the scale gets much larger.

In his work with the Institute of International Education's Scholar

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Changes to *APS News*: *APS News* is shifting to a bimonthly print schedule, with six combined, longer issues per year (January/February through November/December). This shift allows us to focus more resources on fast, accessible storytelling online, where we can better serve the global physics community with timely news. All *APS News* stories, including some not appearing in print, will continue to be published at aps.org/apsnews. Questions? Contact us at letters@aps.org.

Oak Ridge National Lab's graphite reactor churned out plutonium for Manhattan Project

The reactor, now an APS Historic Site, achieved criticality in nine months and had both wartime and peacetime utility.

By Rachel Crowell

Workers used a long rod to push uranium slugs into the concrete loading face of the graphite reactor at Oak Ridge National Laboratory in the 1950s. Credit: ORNL

As U.S. scientists raced to develop the first atomic weapons at the height of World II, one group of researchers, tasked with producing plutonium, had to grapple with its own internal discord.

The Manhattan Project needed vast quantities of plutonium, key to the creation of the bomb. In early 1943, two teams of researchers — scientists from the University of Chicago's Metallurgical ("Met") Laboratory and engineers from the chemical company DuPont — were directed to design a machine for the job at Oak Ridge National Laboratory in Tennessee.

The technical challenges were enormous. The researchers needed to scale the production of plutonium from miniscule amounts to kilogram quantities, a feat that would require creating a nuclear reactor more powerful than any before. But although the two teams were united in their mission, they faced friction.

"There were matters of culture, there were matters of practice, and there were matters of prejudice," says Sherrell Greene, retired ORNL director of nuclear technology programs and research reactor development programs. Many of the University of Chicago scientists who were European were wary of getting involved with military projects because of "the distrust of the industrial military complex that evolved in Europe after World War I," he says. Some of the engineers were distrustful of the scientists.

The scientists also underestimated the challenges involved with plutonium production, including uncertainty around how much plutonium would be needed. "The Manhattan project was about turning the discovery of a physical phenomenon — actually, multiple physical phenomena — into an industrial-scale machine," Greene adds. "It's one thing to do an experiment in a room the size of your garage; it's another thing to produce a machine that runs 24 hours a day, seven days a week, cranking out product."

Still, the team forged ahead, building trust through "the passage back and forth of blueprints, drawings, letters, memos and meetings," Greene says.

On Nov. 4, 1943, just nine months after construction began, the Oak Ridge graphite reactor became the world's second nuclear reactor to achieve criticality — meaning that enough neutrons are released to sustain an ongoing series of reactions — and the first designed for continuous use. Within a few months, the team was producing the world's first few grams of plutonium.

The graphite reactor, also called the X-10 Pile or Clinton Pile, churned out plutonium for the Manhattan Project. The researchers "almost achieved, from an engineering perspective, irreducible complexity," says Greene

After World War II, concerns arose that the site that's now ORNL would be shuttered. However, the graphite reactor "was a life-preserver for the laboratory," Greene says. Even in peacetime, it was used to achieve "an astounding range of applicability" in nuclear energy and medicine, Greene says.

"It had proven itself in wartime, and what it did — by being immediately turned to the production of a wide variety of radioisotopes, both medical and industrial experimental isotopes — is it gave a reason to keep the laboratory operating while it continued to explore and understand the capabilities of the reactors for research and also to build new missions for itself," Greene says.

Mickey Wade, associate laboratory director for ORNL's fusion and fission energy and science directorate and an APS Fellow and member, championed the reactor's designation as an APS Historic Site, in part because of the reactor's far-reaching impacts — including its role in the development of nuclear energy.

"It was truly a demonstration of the ability to generate energy from a nuclear reactor for electricity purposes," Wade says. The graphite reactor had other broad research applications as well. "One of the earliest things that was done on the

Oak Ridge continued on page 4

THIS MONTH IN PHYSICS HISTORY

March 1958: Charles Keeling begins long-term measurements of atmospheric CO2 on Mauna Loa

The Keeling curve deepened our understanding of Earth's workings, and continues to show how fossil fuel emissions are changing the planet.

By Katherine Bourzac

Charles David Keeling. Keeling posted the running narrative of increasing carbon dioxide concentrations on the wall across from his office. Credit: Scripps Institution of Oceanography at UC-San Diego

One of the most important data collection projects on the planet is located on top of the world's largest active volcano, Mauna Loa on Hawaii's Big Island. Measurements of atmospheric carbon dioxide concentrations were started there by Charles Keeling and have been interrupted only twice, once due to funding issues, and once due to natural causes: In November 2022, lava blocked off access and power to the Mauna Loa Observatory.

But the active volcano was the least of Keeling's problems. Over its 67-year history, the Keeling curve has been vulnerable to changes in policy at funding agencies and shifting political winds. Keeling, who died in 2005, spent his entire career measuring atmospheric CO2, and plenty of time and energy fighting to keep the project afloat.

Keeling's impact has been profound. "These measurements have revolutionized our thinking about how the Earth functions," says Rob Jackson, an earth systems scientist at Stanford University.

The Keeling curve revealed that the biosphere breathes. In the Northern Hemisphere, atmospheric CO2 rises in winter, when photosynthesis is slowed, peaking at the start of the spring. When leaves emerge, photosynthesis accelerates, drawing down CO2. The Keeling curve shows this annual inhalation and exhalation of CO2, a seasonal change in the planet's atmosphere that was previously invisible. Keeling's data also help show that this effect is less pronounced in the Southern Hemisphere — and that the planet's rotation contributes to relatively quick atmospheric mixing from east to west, and slower mixing along the north-south axis.

Keeling curve data also helped establish that fossil fuel emissions are increasing atmospheric CO2, and that the planet's land and oceans are not able to take up enough of the gas to counteract human emissions.

"We use these data all the time — they are the foundation of our analysis of emissions," says Jackson, who chairs the Global Carbon Project, an international scientific team that monitors greenhouse gas levels and their sources. The latest Keeling curve data show record growth in CO2 emissions in 2024. Last year, atmospheric CO2 concentrations reached 422.5 ppm, 52% above the preindustrial level of about 278 ppm in 1750.

Though these data are central to earth and climate science, having a long-term, continuous CO2 record was not inevitable.

In the early 1950s, there wasn't much interest in atmospheric CO2. At the time, scientists thought concentrations of the gas were variable. Measurements were sparse, and sometimes unreliable. Keeling became interested in the problem when he was working as a postdoc in geochemistry at Caltech in Pasadena. To calibrate measurements for a study of carbonate rocks in Big Sur, he wanted to make sure he wasn't making assumptions about ambient CO2 concentrations.

"Published values of atmospheric CO2 concentration varied widely," Keeling recalls in an essay published in 1998. He decided to see for himself. His advisor supported his interest in CO2, so Keeling built a pressure-based instrument called a manometer for measuring the gas. He also collected air and water samples at his study site every few hours throughout the day and night — though he had no reason to do so.

"The reason was simply that I was having fun," he writes. He was 27, and he was enjoying being in Big Sur State Park, a beautiful area where redwood forests meet cliffsides above the foamy blue-green waters of the Pacific Ocean. At the suggestion of a colleague, Keeling saved samples for isotopic analysis. "I did not anticipate that the procedures established in this first experiment would be the basis for much of the research that I would pursue over the next forty-odd years," he writes.

His early measurements hinted at what were then unexpected patterns. Afternoon CO2 concentrations were relatively constant, while previous research suggested they would vary widely. Keeling also saw a diurnal pattern. Concentrations were higher at night, and his isotopic measurements suggested this was due to CO2 release from soil and plants.

Keeling's findings came to the attention of Harry Wexler, the head of research at the U.S. Weather Bureau (now the National Weather Service). Wexler had just overseen the construction of an observatory on Mauna Loa in 1956 and was looking for projects to house there. Despite the risk, the volcano is a good place to measure CO2. Mauna Loa's elevation and remote location provide a relatively clean, well-mixed sample of the atmosphere, with less contamination from industrial activity and traffic than would be found in the continental U.S. And the harsh volcanic landscape means the observatory is not influenced by emissions from local plant life.

Wexler suggested to Keeling that he measure CO2 at the new Mauna Loa Observatory, and in other locations around the world, as part of the International Geophysical Year, a collaborative scientific interchange in 1957 and 1958. (The United Nations has declared 2025 the International Year of Quantum Science and Technology.) Keeling got a job at the Scripps Institute for Oceanography at the University of San Diego, where the CO2 program

Charles Keeling on Hawaii's Big Island in 1958, with the summit of Mauna Kea in the background. Credit: Scripps Institution of Oceanography at UC-San Diego

is based to this day, and rushed to design and kick off the program.

Keeling pushed for the project to use infrared spectrometers, which became commercially available after World War II, because the instruments provided accurate, continuous readouts of gas concentrations. "Most of Keeling's seniors thought that such instruments were more costly than anyone needed to

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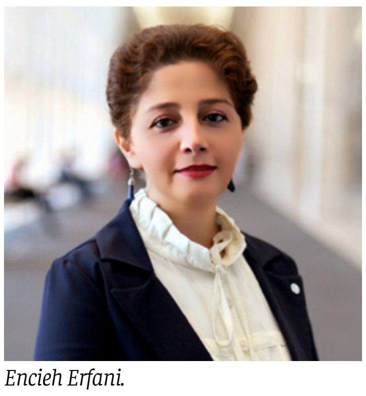
Rescue Fund and the International Rescue Committee, Martin has witnessed the struggles of displaced scientists. He says there's a tendency within the scientific community to assume that moving around as a scientist — even one forcibly displaced — is just a matter of sending out resumes, but the reality is more complicated.

Even if one sets aside the trauma of their circumstances, the challenges of getting to a friendly country, and language and culture obstacles, competing in the STEM job market — often with no local professional network — can be daunting. Degree names, publishing processes, scientific instruments, job titles, and even software packages aren't consistent throughout the world, which means it can be challenging for employers to interpret the qualifications and



Encieh Erfani.

skills of applicants.

"It's not as simple as just dropping displaced scientists and STEM personnel into a different lab," Martin says. "For instance, many scientists in the Middle East were heavily encouraged to write in the journals of their home countries in their native languages, and so they aren't necessarily recognized as being scientific accomplishments in the West."

> "You can very frequently hit a situation where the scientists are opposed to their government at home but punished for the actions of the same government," Martin says.

More broadly, employers may not fully understand the ways displaced STEM workers applied their skills in their home countries. For example, Martin worked with an Afghan engineer who kept roads and services accessible in the countryside during a period of high conflict. Another kept the lights on during the siege and fall of Kabul. "These are people who have clearly demonstrated the ability to do incredible things in their home countries but whose resumes may be a little bit harder to interpret," he says.

In Erfani's experience, institutions willing to host displaced scientists often consider only research excellence and publications. Skills like teaching, outreach, mentoring, and administration may not be valued — or even asked about.

Even if a displaced scientist is offered a position in another country, they may hit a wall that makes it impossible to accept that job — like a denied visa. There are programs to relocate technical personnel, but they can be stymied if the person's home country is under sanctions or has poor diplomatic relations with the host country.

In such cases, "you can very frequently hit a situation where the scientists are opposed to their government at home but punished for the actions of the same government," Martin says.

If that person is permanently displaced with no home to go back to, getting a visa can be even more difficult, Erfani says. Her visa requests often went unanswered, were denied, or experienced long delays, even though she has publicly opposed the Iranian regime that sanctions are levied on. She was thankful to get a temporary fellowship and office at Mainz University in Germany, but she had no path to establishing residency, no lab, and no courses to teach.

"When I resigned, I was a faculty member in Iran, so I had my own group, my own students," she says. At Maintz, she wasn't even "employed by the university, according to their rules."

Erfani spent many of her days applying for positions, trying to get visa requests approved, advocating for at-risk scientists and academic freedom, and taking courses in diplomacy (she's especially interested in science diplomacy). "I packed my luggage for three months, and now it will be two years," she says.

Still, she doesn't regret the decision to resign. And as 2024 drew to a close, she received great news: A long-awaited visa approval came through, and more than seven months after receiving an offer, she could finally accept a position at the Perimeter Institute for Theoretical Physics in Canada. She began work as a researcher this February.

"It is a one-year postdoctoral position, so stability is still uncertain," Erfani says. But she's hopeful, and she has a new goal. "My dream is to pursue a path in science diplomacy in Canada."

For many scientists like Erfani, at stake is an issue of humanity and furthering science. In a June 2024 editorial in Science about scientists in exile, Clemson University professor Gary Machlis and National Academies of Science senior director Franklin Carrero-Martínez wrote, "In addition to providing scientists with a safe haven (the humanitarian principle of 'responsibility to protect'), it is critical to retain their specialized knowledge, expertise, and skills, and position them to aid in rebuilding their countries' scholarly communities and science-based economies and training the next generation of scientists."

Martin concurs. "If we wish to truly maintain science as a global enterprise, then there is this responsibility [to help]," he says. Otherwise, "It becomes a loss of perspective, a loss of field knowledge in particular areas, and, in some cases, if assistance is not there, it actually may mean the longer-term loss of a country's scientific capacity."

Many scientific organizations have established or renewed efforts to support displaced scientists in the last few years. They aim to help those who are temporarily displaced, such as by the war in Ukraine, and maintain their skills and expertise so they can help rebuild their country and its scientific capacity on their return. For scientists who cannot return home, like Erfani, the goal is helping them get to a place where they can continue their scientific pursuits and begin building a new life.

After Germany annexed Austria in 1938, nuclear physicist Lise Meitner — who was Austrian, Jewish, and working in Germany — needed to flee. University of Groningen physicist Dirk Coster helped her escape to Sweden by way of the Netherlands. Credit: Photo by Harris & Ewing, courtesy of the U.S. Library of Congress

You can help.

One way to support displaced scientists is to fundraise for or donate to organizations that support them. Consider those that offer fellowships for displaced scholars, Erfani suggests. Securing one of these fellowships can increase a scientist's odds of finding a host institution, but there are not nearly enough to meet the demand, she says.

Another way to help is to consider hiring displaced scientists or STEM personnel and encouraging those in your network to do so. Giving someone their first position in a new country can be especially important, even if it's a nontraditional, short-term position, says Martin. It helps the person acclimate to the U.S. workforce and demonstrate their technical skills to future employers. It may also help them start to establish residency.

Companies open to hiring displaced scientists and STEM personnel can reach out to organizations like the International Rescue Committee, particularly if they're willing to consider applicants whose skills look a little different or who may need some time to adapt, while researchers can work with groups such as the Scholar Rescue Fund to offer placements.

Advocating for national policies that assist displaced scholars, such as visa programs, is a vital way to support at-risk scholars, says Erfani. In addition, being aware of what is happening around the world, sharing the stories of displaced scientists and STEM personnel, and volunteering with aid and advocacy organizations make a difference.

Physicists have a history of showing up for at-risk colleagues, perhaps most famously during the 1930s when they rallied to support those fleeing Nazi rule, among them Hans Bethe, Albert Einstein, Lise Meitner, and Erwin Schrödinger. The community has advocated for many others, such as Soviet dissident Andrei Sakharov, Tiananmen Square protest leader Liu Gang, Cuban prisoner of conscience Luis Grave de Peralta, and Iranian prisoners Omid Kokabee (arrested for refusing to work on military projects) and Narges Mohammadi (arrested for advocating for human rights).

"Physics has a very proud tradition of supporting the human rights of scientists," Martin says.

This article is adapted from Radiations magazine.

Kendra Redmond is a writer based in Minnesota.

Creating student communities

APS student ambassadors like Danielle Maldonado grow as leaders and share APS resources with their peers.

By Kendra Redmond

From modeling the fluid dynamics of "hairy surfaces" like the human tongue to exploring how physics students learn, Danielle Maldonado has spent her academic journey bridging fields and building a more connected physics community. Now a fourth-year graduate student, she is advancing physics education research while strengthening the physics community through leadership, outreach, and mentoring as an APS student ambassador.

"Physics discoveries are made by people," she says, so the physics community should encourage and invest in anyone interested in physics."It is important to cultivate relationships that uplift and support people in this field and encourage others to do so."

A high school chemistry lesson on atomic orbitals sparked Maldonado's interest in the field. "From that moment, I pretty much knew that I wanted to be a physicist," she says. Maldonado became a physics major at the University of Texas at Austin and conducted research in a biophysics fluid dynamics lab. Maldonado was active in the school's Society of Physics Students chapter, eventually becoming president and supporting department outreach events.

During her senior year, two pivotal moments shaped Maldonado's plan for the future. First, she noticed that several of her peers — particularly students of color and LGBTQ+ students — wanted to leave the field. Second, she discovered physics education research and its aim to improve physics teaching and learning. She decided to pursue physics education research to help create a more inclusive undergraduate experience and someday put what she learned into practice as a professor.

As a graduate student at West Virginia University (WVU), Maldonado studies how students' self-efficacy and sense of belonging evolve over the calculus-based introductory physics sequence. One of her findings is that self-efficacy, a student's belief in their capacity to perform a task adequately, tends not to evolve linearly over the two-course sequence. Instead, it often decreases during the first semester, then rebounds by the time students start the next course. She also explores whether students' self-efficacy and sense of belonging are impacted by demographics such as first-generation college student status, gender, and minority status.

Maldonado's commitment to physics at WVU isn't limited to the lab. She has served as president and vice president of the school's Physics and Astronomy Graduate Student Organization, and she served on the organizing committee for WVU's 2024 APS Conferences for Undergraduate Women in Physics.

Maldonado's first foray into professional service with APS came in 2023 when she was elected to the APS Forum on Education Executive Committee. She now serves on the APS Forum on Graduate School

Danielle Maldonado.

Affairs Executive Committee and as an APS student ambassador at WVU, representing the society on campus and connecting her fellow physics students with APS resources and opportunities.

"Not everyone has time to go out of their way to look for extracurricular opportunities that can advance their education or careers when they are balancing classes and research," Maldonado says. As an ambassador, she works with APS to spread the word about webinars, travel and outreach grants, and other resources directly to target audiences, like students in a particular subfield.

This spring, hundreds of local families are expected to attend a Magic of Physics show organized by WVU's Physics and Astronomy Graduate Student Association. The new event is supported by a grant from the APS Forum on Outreach and Engaging the Public, which Maldonado identified through her work as an APS ambassador.

"In my capacity as a student ambassador, I was able to connect people with these resources and shoulder that burden for them," she says.

Maldonado sees her efforts as a way to support her local physics community and hone her leadership skills. "The APS Student Ambassador program is a great introduction to APS if you want to take on more leadership in the future," she says.

The program is open to undergraduate and graduate students at any degree-granting institution. Applications for the 2025-26 cohort are due April 4.

New ambassadors engage in virtual professional development sessions over the summer to learn about APS and develop their communication and leadership skills. Then, during the academic year, they host an information-sharing event, pass on APS-related opportunities to their peers, and promote the society in coordination with APS staff and fellow ambassadors. They may also be invited to attend the Annual APS Leadership Meeting or other APS meetings with travel support.

As a student ambassador, you learn how APS opportunities can help you and your community, says Maldonado. "Getting involved in this organization and sharing those resources with others will be immeasurable in your career."

To join the next cohort of APS student ambassadors, apply by April 4, 2025. Not an APS member? Become one today to shape the future of physics, advance your career, and support peers as a student ambassador.

Kendra Redmond is a writer based in Minnesota.

Keeling Curve continued from page 2

Keeling in the laboratory. Credit: Scripps Institution of Oceanography at UC-San Diego

measure something that fluctuated so widely as atmospheric CO2 levels," writes Spencer Weart in the website accompanying his book The Discovery of Global Warming. "Yet the IGY money pot was big enough, and Keeling persuasive enough, to get Wexler to dig up funds to buy the spectrophotometers." They were installed in Hawaii and at a station in the Antarctic. On March 29, 1958, Keeling's first Mauna Loa reading came in, measuring atmospheric CO2 concentration at 313 ppm.

After just one year of data collection, both stations showed a rise in CO2 — a surprise. Keeling and his colleagues kept collecting data, and began publishing papers detailing and interpreting it. But as he notes in his 1998 essay (appropriately titled "Rewards and Penalties of Monitoring the Earth"), the CO2 monitoring program came in and out of fashion with various funding agencies.

There's a small gap in the Keeling curve in 1964, when instruments broke down after funding cuts. Keeling's measurements in Antarctica ceased. In the 1970s, interest in global warming attracted government attention to the project, and proposals that it be transferred to a government agency — moves Keeling successfully resisted. "One more year," funders frequently warned.

Weart estimates that all this attention and government and scientific labor was expended over a research project that cost only about $200,000 a year — a drop in the bucket of the U.S.'s federal budget.

"Why Go On?" asks a heading in Keeling's biographical essay. He answers, "the data gathered in my program became more fascinating as the records lengthened." And he wanted to stay involved to make sure those data were high-quality, having found issues with the methods being pitched and developed by the federal agencies that proposed to take over CO2 monitoring.

The Scripps CO2 Program continues to this day, under the auspices of Ralph Keeling, Charles' son. The curve is bolstered by measurements performed by U.S. government agencies and other scientific teams around the world. But the Mauna Loa Observatory and the Keeling curve have unique scientific importance, in part due to the long-term continuity of the data, says Jackson.

"This is the most unique and perhaps the most important dataset in earth science," he says.

Katherine Bourzac is a science writer based in San Francisco.

Oak Ridge continued from page 2

Ernest Wollan and Clifford Shull conducted some of the first neutron scattering experiments using this diffractometer at the graphite reactor in 1950. Credit: ORNL

graphite reactor was to put a neutron diffraction capability on it, which now we call neutron scattering" — a technique that has since been used to study fuels, batteries, and other materials.

The graphite reactor was shut down in 1963 and has been a museum since then. Today, ORNL visitors can explore the history and impact of the sleeping giant.

According to Wade and Greene, the graphite reactor is an example of what can be achieved through multidisciplinary collaboration. "[It] was not imagined to be a neutron scattering device or an isotope production device," Wade says. "This is all about the learning process, the discovery process we have as scientists, as we take what's available to us."

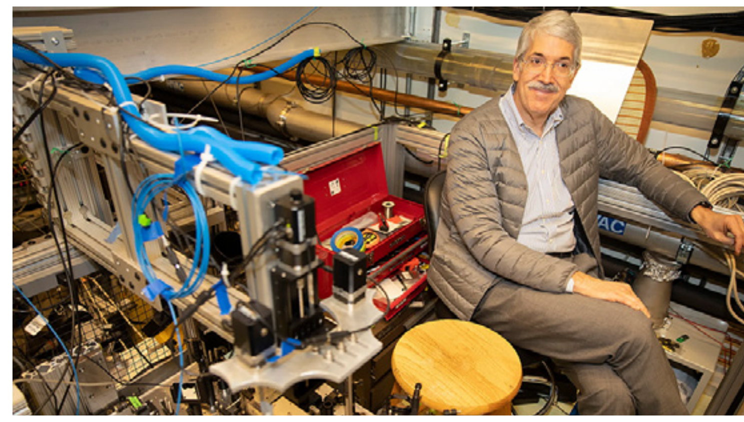
By first learning "one thing or two things," he adds, the result is "a cascading effect" that results in "a capability that's world-changing."

Rachel Crowell is a science journalist and editor based in Iowa.

John Doyle continued from page 1

to earn a Ph.D. focused on ultracold atomic hydrogen, also from MIT. After working as a researcher at AT&T Bell Laboratories and MIT, he joined the Harvard physics department in 1993, where he is now the Henry B. Silsbee Professor of Physics.

Doyle spoke with *APS News* about his journey into the field of atomic, molecular, and optical physics and the opportunities he sees in the coming year for science and for APS. This interview has been edited for brevity and clarity.



Doyle in the lab. Credit: Kris Snibbe/Harvard University

Tell us about your academic journey and how you got interested in physics.

I went to MIT as an undergraduate. I started majoring in computer science, but at MIT everybody has to take physics. I was lucky enough to have this influential instructor in my first physics class, Dan Kleppner. His explanations were super clear, and whenever he could, he threw in a joke. That experience made it feel like physics has a human side to it, that you could have fun while you're doing things which are very mathematically oriented.

What got me hooked on physics was working in a lab co-led by Kleppner and Tom Greytak with an amazing postdoc, Harald Hess. The idea was to make a Bose-Einstein condensate out of atomic hydrogen. The fact that you could make a gas out of atomic hydrogen was amazing to me, but also, the idea that you could produce a macroscopic quantum fluid using techniques which were a combination of atomic physics and cryogenic condensed matter got me very excited. And, of course, there's the fun of working with cryogenics.

What research questions interest you and your group?

I work in two areas, both of which involve creating cold or ultra-cold molecules and then detecting the molecules using laser spectroscopy. These molecules are powerful tools, not only to develop new quantum information systems but also to answer fundamental questions about particle physics and cosmology.

One of the things we're interested in is answering the question of why there is a matter-antimatter asymmetry in the universe. There are many theories that look good, but we don't really have the microscopic candidate — the particle source of what we call charge parity violation — that's needed to describe this asymmetry.

Generically, there is predicted to be a particle with enough CP violation. If that particle exists, it can be sensed by the electron or proton or other fundamental particles and endowed with an electric dipole moment. If we see this electric dipole moment, we can directly say that a particle exists and could explain the microscopic origins of matter-antimatter asymmetry.

Another overarching theme in our work is quantum control — being able to put an atom or molecule into any quantum state you want, then couple molecules together and use those as a quantum information processing system. How big a molecule can you make ultra-cold and control the internal quantum state? This is an interesting question of complexity.

Are there major findings, either from your group or the broader field, that you feel have elevated atomic, molecular, and optical physics research?

One recent exciting finding is that we can have full quantum control over a triatomic molecule — we can put it in any quantum state, rotational state, or vibrational state. We can also make optical tweezer arrays of individual polyatomic molecules, where we use light beams to hold individual molecules. This means we can not only determine their internal quantum state — we can also hold them in space very precisely.

Another exciting finding — not from my group — is making more precise optical atomic clocks, using lots of atoms held in egg carton potentials of light. I point this out because the precision of these clocks has been getting better, Moore's-law-style — where every few years, the precision doubles. If you look in the past in physics, clock precision is a bellwether. Being able to make measurements more precisely will feed into other science or technology. We can have confidence that the field of AMO will be healthy for another decade or two, at least.

How did you first get involved with APS?

I first came in contact with APS, as many members do, as a graduate student. At that time, I took APS for granted — that this organization existed, it was run well, it ran meetings, and we had our research findings that we would submit to APS journals. In a sense, it's a sign of a healthy organization when the students take it for granted that everything is functioning well.

One reason I stood for election was that I realized that we shouldn't take things for granted, that there's work that goes into all the important activities that APS does: our lobbying in Congress, setting of policy, standards for the field, outreach. I felt that I should do my part to keep this great organization going and running so well.

What are your goals while serving as APS president?

One thing I'm excited about is the International Year of Quantum Science and Technology. Quantum mechanics is one of the foundations of modern science. It also has mysterious-looking aspects that can get young people excited and has been talked about a lot in the media and entertainment, so the soil is there to grow excitement among young people for doing science.

We're also hosting the Global Physics Summit in March. The summit has a record number of abstract submissions, and it will have satellite sites — more than ever before — where physicists and aspiring physicists will join from around the globe, so this meeting is an opportunity to promote science more broadly.

We should also focus on maintaining and improving our publishing. One of the things that open access publishing models have driven is getting researchers to think in new ways about the best place to publish a paper. We want researchers to understand that if you publish in APS journals, which are purpose-led, everything that goes into our organization is for the good of science.

What challenges lie ahead, either for APS as an organization or for the scientific community a whole?

Funding for research is getting tighter, and that's a challenge we all feel. Finding new ways to support physics and help researchers do their best is only going to grow in importance.

It's no secret that public trust in science has taken some hits recently. I'm interested in exploring how we can expand our work to connect with people, to share the amazing work that physicists are doing, and to let people at all levels know that physics is having an impact on their lives.

What do you see as the opportunities ahead?

The problems we face today are huge, but not unprecedented. What is unprecedented is the opportunity to connect more broadly. Language barriers are eroding, and there's a growing cultural commonality, especially among young people.

APS plays a very active role in communicating to our elected leaders and to the public about why physics is important — our policy is truth, and we tell the truth about science. Truth is our superpower, and we should speak out about science, even when the climate is a difficult one. We make that our most important focus whenever we're discussing issues of importance to the country.

This is an amazing time for science and physics. We're lucky to be alive when so many ideas are being developed — so many new techniques and connections to other sciences. It's extremely exciting.

Erica K. Brockmeier is the science writer at APS.

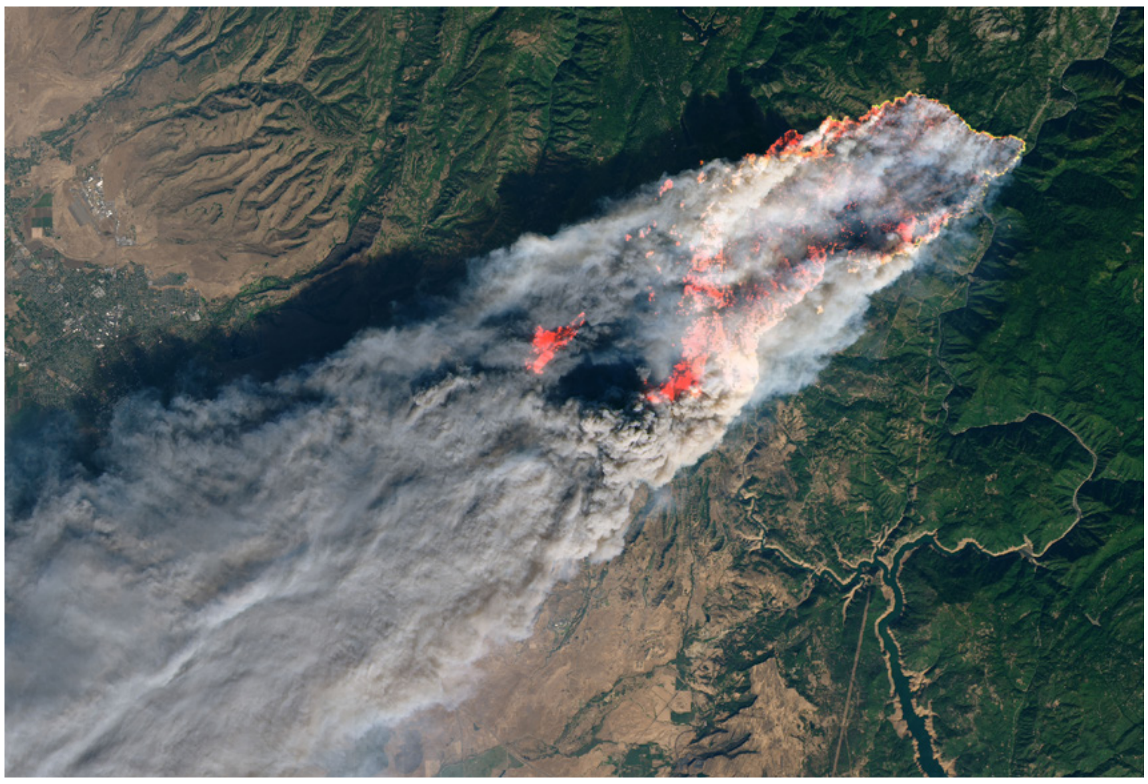
APS Fellow at Georgia Tech wins 2025 Japan Prize

Russell Dean Dupuis, professor of electrical and computer engineering at the Georgia Institute of Technology and an APS Fellow, has been awarded the 2025 Japan Prize in Materials Science and Production.

Dupuis was recognized for development of metalorganic chemical vapor deposition, or MOCVD, a technique that revolutionized the mass production of compound semiconductor devices. His work in the 1970s demonstrated that MOCVD could create high-performance semiconductor devices suitable for practical use. The method has become critical in the manufacturing of LEDs, laser diodes, and high-efficiency semiconductor solar cells.

The Japan Prize, one of the world's most prestigious awards in science and technology, includes a certificate of merit, a commemorative medal, and a cash award of 100 million yen, or approximately $650,000. APS congratulates Dupuis on this outstanding achievement.

Carbon Removal continued from page 1



The 2018 Camp Fire, the deadliest and most destructive in California's history, shown here with visible and shortwave-infrared light to highlight active fire. Climate change is intensifying fires, a potential threat to reforestation as an ecosystem-based approach to carbon removal. Credit: NASA Earth Observatory/Joshua Stevens

Major findings of the report

Human activity emits a total of 35 billion tonnes (35 gigatons) of carbon dioxide every year. Given the scale-up effort needed, removing just 1 gigaton would be the equivalent of a baseball batter "getting on first base," says Marston. Yet at a time when the world is trying to bring as many new renewable energy producers online and drive down annual emissions, diverting clean electricity to carbon capture efforts would be "a huge ask," he says.

Even so, the report provides a summary of the carbon dioxide removal technologies in the pipeline, distinguishing between once-through and cyclic approaches, in part because the categories have distinct energy and material needs.

Taylor uses a simple metaphor to distinguish between these two approaches. "Imagine we are in a boat full of water," he says, and "we are in danger of sinking." To get the water out, we could either run through a bunch of paper towels, or we could use one sponge, and put in the extra effort — energy — to squeeze out the sponge before reusing it.

Paper towels represent a once-through process: We use a paper towel and discard it. But a sponge is cyclic, because we could use it "over and over without using up any materials," he says.

One cyclic removal technology is chemical direct air capture, which relies on a solvent or solid sorbent to 'capture' carbon dioxide from air that fans pull through the system. Because the carbon dioxide in the atmosphere is dilute — just 420 molecules of every million molecules in the air — "a lot of energy has to be expended just to concentrate the carbon dioxide in the air," says Marston. It's an example of "basic physics at work."

Compressing the carbon dioxide into a liquid and injecting it into the ground requires even more energy. Plus, to remove 1 gigaton of carbon dioxide — just 3% of what humans add every year — these systems would need to process the same amount of air that all the air conditioners in the world currently process in one year.

And to have a significant impact, Marston says these systems would have to consume power "comparable to a large fraction of the total electric power output of the United States" — one of the highest energy producers and consumers, per capita, in the world.

The report explores two once-through approaches: enhanced rock weathering and ocean alkalinity enhancement, both of which rely on finely ground minerals. The minerals could be scattered across a land surface to suck carbon dioxide out of the air or mixed into ocean water, to drive up its alkalinity and enable carbon dioxide absorption from the air above.

"The reactions are generally exothermic," meaning they don't require energy inputs to capture the carbon dioxide, Marston says. This reduces the total amount of energy needed to capture a comparable amount of carbon dioxide as a cyclic process, but it also requires more material. To have a significant impact, we would need to quarry and process a similar amount of rock as we do for the global production of cement — the binder used in concrete, the most-consumed material on the planet.

Columns of basalt in Iceland. Basalt is one of the candidates for enhanced rock weathering, a proposed method of carbon removal. Credit: Jonathan Larson

The report also considers ecosystem-based approaches, which allow the natural environment, like trees, grasses, and soil, to capture and store carbon. In many cases, Taylor says, these approaches are "more economical than engineered approaches and can have a variety of co-benefits, such as improving water and air quality and helping with the biodiversity crisis," though he cautions that ecosystems are vulnerable to carbon-releasing events like wildfires.

Recommendations for policy-makers

The report's authors acknowledge that carbon dioxide removal may one day be necessary, despite its energy costs. Thus, the report recommends that R&D investments in CDR technologies still be pursued — but only "selectively and prudently."

"These kinds of technologies are something that we need to explore and have ready if necessary," says Marston. "But whether they can be scaled up is a big question," which is why the report also emphasizes that reducing carbon emissions today is the most direct way to decrease future carbon dioxide levels.

Marston gives an example of a geothermally powered direct air capture plant recently brought online by Climeworks in Iceland. The plant made splashy headlines, billed as the first "large-scale" CDR plant in the world — "but you would need a million of those plants to absorb all of our annual carbon emissions," says Marston. Scaling up enough to have a meaningful impact would require a "mind-boggling" amount of effort and energy, he says.

This is why the report also suggests ecosystem-based approaches, like reforestation and shifts in agricultural practices, which can be cheaper and help reverse the disruption of human activity.

"Certain ecosystem-based CDR approaches could be our chance to get some part of this right," Taylor says, despite factors that limit their potential, like conflict over land usage and difficulty guaranteeing long-term durability. For example, wildfires are unpredictable — and increasingly common.

The report further cautions that effective planning for carbon dioxide removal will require extensive new generation of carbon-free power, like solar or nuclear, and that once-through approaches still need their effectiveness confirmed before being considered for wide-scale deployment.

"The main drawback is you're dealing with this open system" — an ocean with currents or a field subject to runoff into a river during rain — that makes it "very hard to quantify how much carbon dioxide is actually being absorbed," says Marston. "How to quantify this measurement is very important and much less straightforward than it is for direct air capture."

For this reason, the report underscores the need to develop reliable systems of measurement, reporting, and verification, so that scientists will know if efforts are working and whether countries are actually meeting targets. "That will require rigorous standards," says Marston — akin to international standards for methane emissions and fluorocarbons.

Lastly, the report recommends that policymakers develop economic and policy frameworks for carbon management, and weigh the benefits of implementing large-scale carbon dioxide removal technologies against approaches for reducing emissions.

Can we solve climate change?

Taylor, a physicist who specializes in energy systems, says that as recently as 2006, "the real story" of climate change still wasn't clear to him. He wanted to learn more, and in 2021, his interest in climate change led him to POPA. Marston joined the panel a year later.

Although APS had previously published a report on direct carbon capture from the atmosphere, it didn't take much for another POPA member, Bill Collins, to convince Taylor to revisit the topic. "The field has been advancing rapidly," says Marston. The timing was right.

Marston's own interest in climate physics dates to his graduate studies. "It was around the time that Jim Hansen, the NASA scientist, testified to Congress that there was a sign of global warming," he says.

In his 1988 testimony, Hansen reported that air temperature data from several meteorological stations indicated 0.5-0.7 degrees Celsius of warming, on average. With records indicating warming across both hemispheres, Hansen told Congress he was "99 percent sure" the evidence pointed to a global warming phenomenon. He also noted that 1987 was one of the two warmest years in the entire historical record.

In 1989, the United Nations established the Intergovernmental Panel on Climate Change to provide a deeper scientific perspective. Predictions given in the IPCC's first report, published in 1990, included more severe droughts and heat waves, more powerful hurricanes and typhoons, and a sea level rise of 11 to 38 inches.

With the IPCC's Sixth Assessment Report on the topic published just three years ago, in 2022, humanity has now witnessed every major prediction of its first report.

"The evidence is that people are not acting quickly enough and that the impacts of climate change will get worse and worse," says Marston.

That's why climate science research is vital, says Taylor. "We cannot make intelligent decisions as a society about how to move forward without understanding what is happening with [our] climate ... [and] physicists can play an important role in this effort."

Human activity — largely the burning of fossil fuels — emits 35 billion tonnes of carbon dioxide each year. Credit: Chris LeBoutillier

While the POPA report focuses on the science of carbon dioxide removal from the atmosphere, Taylor says the core message is that "it will take a lot of energy and material to do CDR at the gigaton scale" needed to have an appreciable impact. Hence, the clear need for "a system of policies that balances the challenges of CDR with the challenges of curbing carbon emissions," he says.

"This is a complex problem, but at this point, climate and carbon management is really a social and economic challenge," says Taylor. In other words, scientists know how to solve the problem. But can world leaders work together and devote the necessary resources to put effective solutions in place?

Until then, Marston cautions that the dramatic weather events we've witnessed in recent years are "just a taste of what's to come."

Liz Boatman is a materials scientist and science writer based in Minnesota.

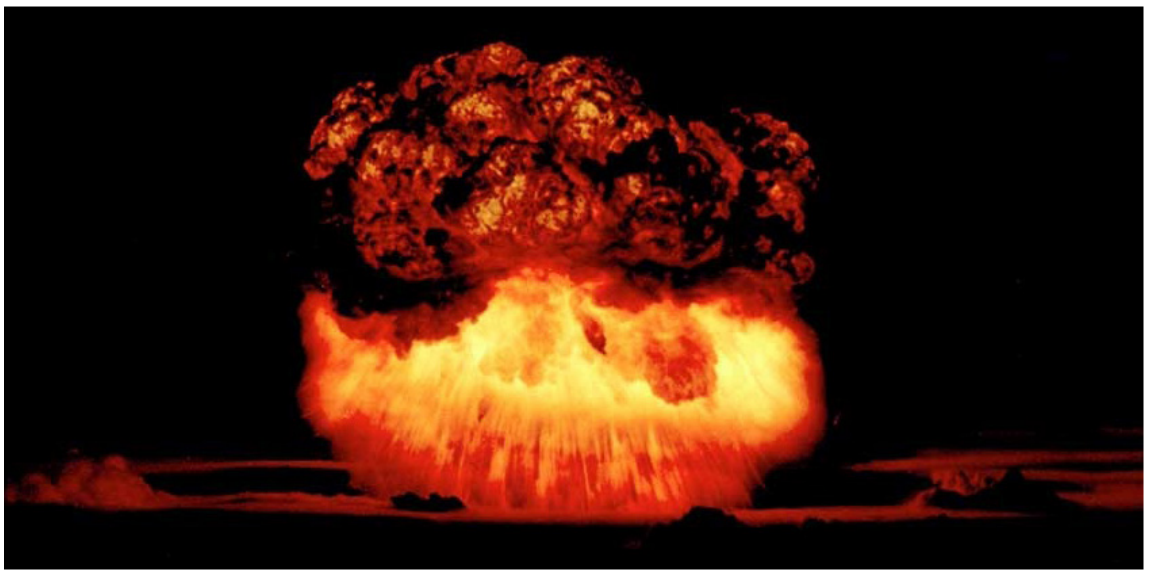
BACK PAGE

Confronting the bomb

Physicists have rallied against nuclear weapons for 80 years — and must do so again.

By Zia Mian, Stewart Prager, and Frank von Hippel

A dangerous acceleration in the nuclear arms race is underway. The United States and Russia — which together hold almost 90% of the world's nuclear weapons, at more than 5,000 warheads each — are building a new generation of nuclear weapons and delivery systems to replace their Cold War-era arsenals. China may now possess about 600 nuclear warheads. The United Kingdom, France, and Israel are upgrading their arsenals, while India, Pakistan, and North Korea are developing and growing theirs — and all the nuclear armed states and NATO regularly rehearse their nuclear war plans. Russia, amid its war on Ukraine, has repeatedly threatened to use its nuclear weapons.



The Castle Bravo test, the largest nuclear weapon detonated in U.S. nuclear weapons testing, in 1954. The following year, Bertrand Russell, Albert Einstein, and nine other leading scientists and intellectuals published a manifesto on the dangers of nuclear weapons, urging world leaders to "remember your humanity, and forget the rest." Credit: Photo from atomicarchive.com. Public domain.

Two different roles for physicists have re-emerged. Some are being recruited to maintain, design, and develop nuclear weapons, continuing a practice that began with the Manhattan Project 80 years ago. Others are working to reduce and end nuclear dangers, following in the footsteps of scientists like Hans Bethe, Nobel laureate and former head of the Manhattan Project's theoretical division, who in 1997 urged President Bill Clinton and "atomic scientists in the laboratories" to "cease and desist from work creating, developing, improving and manufacturing further nuclear weapons." As the founders of the Physicists Coalition for Nuclear Threat Reduction, we agree with Bethe.

This split within our community also reflects a deeper truth: Physicists have unique influence over how society thinks about and manages nuclear weapons. We understand both their technical realities and the catastrophic consequences of nuclear war. When physicists speak about nuclear dangers, the public and policymakers tend to listen.

Despite the deep cuts in the number of U.S. and Russian warheads since the Cold War, the nuclear world order has taken a turn for the worse.

Physicists have long organized and pushed for nuclear restraint and disarmament. In 1946, in the shadows of Hiroshima and Nagasaki, Albert Einstein founded the Emergency Committee of the Atomic Scientists, which worked with unions, women's groups, media organizations, and others to alert the public about the danger, and to mobilize people against the weapons. Starting in 1957, scientists — inspired by the Bertrand Russell–Albert Einstein Manifesto's call to "remember your humanity, and forget the rest" — convened in the "Pugwash Conferences" to break down Cold War mistrust and develop the technical foundations for nuclear arms control agreements. That same year, physical chemist Linus Pauling rallied 11,000 scientists to petition for an end to nuclear testing, contributing to agreements to ban testing everywhere except underground. In the late 1960s, physicists Richard Garwin and Hans Bethe helped the public and Congress understand that simple countermeasures could neutralize proposed missile defense systems, contributing to the landmark 1972 treaty limiting missile defenses and making it possible to cap Soviet and U.S. nuclear build-ups.

It was not just American physicists. In the Soviet Union, Andrei Sakharov, who shared Pauling's concerns, helped convince Moscow to agree to the 1963 Partial Nuclear Test Ban Treaty (both he and Pauling received Nobel Peace Prizes). In Britain, Patrick Maynard Stuart Blackett, a physics Nobel laureate, opposed the development of nuclear weapons there, a position for which he was condemned.

Today, physicists' voices are needed again. Despite the deep cuts in the number of U.S. and Russian warheads since the Cold War, the nuclear world order has taken a turn for the worse. U.S. nuclear arsenal managers and Congress assume that confrontations with Russia and China require an expanded U.S. nuclear arsenal with new capabilities. This disregards the fact that the current U.S. arsenal is already more than capable of threatening both countries as functioning societies, with devastating environmental and economic effects that would ripple across the world. Indeed, in 2013, after a comprehensive review by the Department of Defense, the White House determined that the U.S. nuclear arsenal could cover all nuclear targets in both countries, plus North Korea, with one-third fewer deployed strategic warheads than the 1,550 weapons permitted by the current U.S.-Russia New START agreement.

Nevertheless, the U.S. plans to spend $50 billion or more per year for decades on a new nuclear arsenal. How did we get here? The current cycle of U.S. nuclear "modernization" was launched 15 years ago by the Obama administration, in exchange for the required two-thirds vote of the Senate to ratify the New START treaty. Then the first Trump administration began to dismantle nuclear arms control agreements, continuing a practice started by President George W. Bush, who in 2002 pulled the U.S. from the Anti-Ballistic Missile Treaty. The Trump administration also withdrew from the 1987 Intermediate-Range Nuclear Forces Treaty, refused to extend the New START Treaty, ruled out ratification of the 1996 Comprehensive Nuclear Test Ban Treaty, and discussed renewed nuclear weapons testing — threatening the moratorium under which no nuclear-armed state other than North Korea has tested since 1998.

In 2021, just before New START expired, the incoming Biden administration agreed with Russia to extend the treaty for five years, but that extension will run out in a year and the treaty cannot be extended again. If it is not replaced, 2026 will be the first year since 1972 in which there are no treaty constraints on the two largest nuclear arsenals in the world.

In its current nuclear weapons Stockpile Stewardship Program, the U.S. National Nuclear Security Administration has called for "shortened development cycles" for weapons, and "enhancing production throughput" through "expansion of production infrastructure to support increased production scope and increased number of weapon system builds." The plan includes new-design warheads for "anticipated future threats," including for land-based intercontinental ballistic missiles, bombers, and submarines. To support this expansion, the NNSA plan proposes to recruit a "next generation of weapons designers and engineers" by providing "new opportunities for students through increased academic fellowships and grant programs" and "[building] new academic alliances."

This appears to go well beyond the original nuclear warhead Stockpile Stewardship Program, which was founded with the intention, in the words of President Clinton, to ensure "existing nuclear weapons remain safe and reliable" [emphasis added].

In the face of these developments, independent physicists can provide a crucial voice for diplomacy and restraint. This is not easy: While the work to build nuclear weapons has been institutionalized in laboratories that receive billions of federal dollars each year, have ample congressional and industrial support, and are operated by for-profit private contractors, those working full-time to reduce the threat are based in small groups in universities, or in nonprofits dependent on scarce philanthropic funding.

With these concerns in mind, we founded the Physicists Coalition for Nuclear Threat Reduction in 2019 as a project of Princeton University's Program on Science and Global Security. Our aim was to develop a network of physicists to advocate for reducing the threats from nuclear weapons through deep cuts in nuclear arsenals, reforms in nuclear force postures and policies, and fulfillment of the international obligation to achieve nuclear disarmament. Supported for its first two years by the American Physical Society's Innovation Fund and continuing funding from the Carnegie Corporation of New York and individual donors, it has partnered since 2022 with the Arms Control Association.

Our team of 15 volunteer physicists have visited over 170 institutions across the U.S. and Canada — mostly university physics departments, but also nuclear engineering departments and national labs — giving colloquia on technical and policy aspects of nuclear arms and engaging in discussions about policy changes to mitigate the dangers of nuclear war. Technical topics are wide-ranging, from warhead physics to the physical effects of nuclear war to verification science. Policy discussions have touched on declaratory policies, such as a no-first-nuclear use; nuclear weapon postures, such as launch on warning; and the new United Nations Treaty on the Prohibition of Nuclear Weapons.

Since the coalition's founding, about 1,500 scientists have joined; half of them are early in their careers.

The coalition offers educational webinars, a monthly newsletter, and one-year, unsalaried fellowships that let early-career physicists and engineers work with senior experts on a research project, attend workshops, and participate in congressional briefings. In 2024, 36 coalition members visited Washington over two days to engage members of Congress on less dangerous nuclear weapons postures. The coalition also launched a program for members to reach out to congressional representatives in their districts.

The coalition now aims to expand efforts to European NATO countries. The U.S. has an estimated 100 nuclear weapons deployed across six bases in Belgium, Germany, Italy, the Netherlands, and Turkey, and appears poised to resume basing in the United Kingdom. France has nuclear warheads of its own, as does the United Kingdom, which also leases ballistic missiles from the U.S. There are many policy issues worth discussing, such as whether NATO should adopt a no-first-nuclear-use posture.

Physicists interested in joining and supporting the coalition can contribute in several ways. Those in academia can host coalition speakers on their campus, organize courses and discussion groups for faculty and students, and contribute technical expertise on nuclear weapons to local peace groups. Through the coalition, physicists can also receive news about key developments and opportunities for engagement with like-minded peers in the scientific and arms control community, members of Congress, and the public.

As nuclear restraint is cast aside, arsenals are modernized and expanded, and governments adopt more belligerent nuclear postures, we physicists can play a key role in reminding policymakers and the public that these weapons make the world less safe — and raising the question to our scientific colleagues whether building civilization-ending weapons is a worthy legacy.

Now, as in the past, we can work to create a nuclear weapon-free world, and a more peaceful future for humanity.

Zia Mian is a physicist and co-director of Princeton University's Program on Science and Global Security (SGS). Stewart Prager is a professor emeritus of astrophysical sciences at Princeton and affiliated with SGS. Frank von Hippel co-founded SGS in 1974 and is a physicist and professor emeritus of public and international affairs at Princeton.

The authors co-founded the Physicists Coalition for Nuclear Threat Reduction in 2019. To learn more about the coalition or join, visit physicistscoalition.org.

APS Campaign continued from page 1

funded research and programs on you, your community, city, and state. Share what would be lost if support for basic research evaporates. Tell us if you've been affected by recent executive actions at go.aps.org/4bDvQMF.

Soon, you'll be invited to participate in the Contact Congress campaign that we will launch as soon as the federal FY'26 budget cycle begins (currently anticipated in April).

Finally, we're looking for enthusiastic volunteer advocates to meet with elected officials and policymakers in key states, work with APS staff to write persuasive op-eds and letters to the editors, attend local town halls, and make sure America's leaders and voters understand why science matters.

To stay updated on our advocacy, join our advocacy email list at info.aps.org/advocacyupdates. Allies outside APS are welcome to join as well.

These efforts are the beginning of a campaign that will address not only the future, but also what's happening right now. More work is in motion to protect science and support physicists, including those whose employment has been disrupted. You can expect additional updates soon, and throughout the year.

We stand in a pivotal moment, and we will meet it with focus and resolve. Please join us in raising our voices for the good of science.