Climate change is a terrific illustration because it is an intensely researched scientific topic and a contentious public issue. It brings together scientific understanding, policy, and politics, and it is both politically challenging and crucial to everyone's future.

So what are the scientific conclusions at the foundation of evidence-informed policy deliberations on climate change?

► **Climate change is extraordinarily dangerous to humanity and all life.** That is because climate, and its stability within a relatively narrow range, is a requirement for life as we know it. The global change in climate people are causing is larger and faster than any humanity is known to have endured since beginning the societal transition from hunting and gathering to agriculture.[1] The physical characteristics of the planet, biological systems and the resources they provide, and social institutions that humans have created all depend heavily on climate, are central to human well-being, and are sensitive to climate change.

► **Solutions are available and highly promising—a serious reason for optimism.** Greenhouse gas emissions are an economically harmful market failure—a classic example of an economic externality. Those who emit pollution to the atmosphere shift the costs of climate damage onto everyone, including future generations. Making emitters pay for all the costs of their use of the atmosphere would help correct that failure and thereby improve economic well-being. Regulatory approaches can speed the adoption of best practices and better technologies, or promote fairness and the public interest. As a result, reducing greenhouse gas emissions can increase climate security, national security, the well-being of people and biological systems, and economic vitality. Existing and emerging technologies, such as rooftop solar panels, electric vehicles, and electric heat pumps, can reduce greenhouse gas emissions, improve air quality in homes and cities, and often provide superior products or services. Building resilience against climate impacts makes communities stronger and better able to deal with both existing vulnerabilities and emerging threats.

Comprehensively addressing the dangers of climate change will require two things: reducing, and ultimately eliminating, climate pollution as soon as possible and building the capacity to avoid—when possible—and otherwise overcome the consequences of climate change.

► **Broad scientific conclusions, like those described briefly here, result from decades of intensive research and examination.** The scientific evidence has been assessed comprehensively and repeatedly by independent experts convened by highly respected scientific institutions. Accuracy is central to credibility for scientific institutions, including the US National Academies of Sciences, Engineering, and Medicine; the American Meteorological Society (for which I work); and the American Association for the Advancement of Science, all of which have assessed climate science. I am not aware of any contradictory assessments from a credible scientific institution. People who target public audiences with messages that contradict broad scientific conclusions are not credible.

People are changing climate, and it poses serious dangers to humanity. A wide range of response options are well understood and would be broadly beneficial, if implemented. Scientists who are up to speed with the evidence have the opportunity to help inform societal deliberations on climate change. That contribution will be crucial for the advancement of evidence-informed policy responses. If scientists, recognizing that societal decisions go beyond science, provide information so that it enables broad public participation in decision making, even among those whose values and preferences differ, then they will simultaneously advance science and strengthen the broader society that they serve.

Therein lies an even greater opportunity for scientists and humanity. If scientists can engage effectively with the broader society to address the climate problem, they may contribute to a template for the wide range of challenges and opportunities facing humanity at this point in the 21st century.

Reference

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LETTERS

Antiquark asymmetry

It was interesting to read the item by Johanna Miller (Physics Today, May 2021, page 14) on the asymmetry between up and down antiquarks in the proton. It does indeed provide fascinating insight into the quark structure of the proton and especially the role of chiral symmetry, which requires that the proton be surrounded by a pion cloud.

But I feel that it is necessary to add a little to the incomplete discussion of the history of that asymmetry discovery. Using the cloudy bag model, which successfully incorporates chiral symmetry into the MIT bag model, I predicted the asymmetry[1] in 1983, almost a decade before the violation of the Gottfried sum rule was experimentally confirmed.[2]

The mechanism is the dominance of the π^+–neutron configuration when the proton emits a pion. The pion contribution to deep inelastic scattering was first mentioned by J. D. Sullivan and Richard Feynman and is often referred to as the Sullivan process. In 1983, however, almost no one in the high-energy-physics community took the idea of a contribution from the pion cloud seriously, as deep inelastic scattering was such a short-distance phenomenon; the constraints of chiral symmetry there were not understood. Certainly no one else, including Sullivan, had discussed the process as a source of flavor asymmetry.

In a November 2021 letter (page 11), Edward Shuryak describes an alternative explanation of the effect and suggests that lattice quantum chromodynamics can be used with the Δ baryon to test the mechanism. The idea of using lattice quantum chromodynamics calculations of the Δ^+ to test the role of chiral symmetry in generating such an asymmetry was published several years ago.[3] In particular, one can expect a significant enhancement of the asymmetry as the pion mass approaches the Δ–nucleon mass difference from above.

References

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2. P. Amaudruz et al. (New Muon collaboration), *Phys. Rev. Lett.* **66**, 2712 (1991).
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ITER's net loss

In July 2020 Physics Today published a letter from Wallace Manheimer (page 10) written in response to the article "The challenge and promise of studying burning plasmas" by Richard Hawryluk and Hartmut Zohm (December 2019, page 34). Manheimer criticizes the international fusion experiment known as ITER and the prospects for commercial fusion. I would like to point out an error in Manheimer's calculation, which, as it turns out, further supports his criticism.

Manheimer asks what the results of ITER would mean for power production. He applies a conservative thermal-to-electric power conversion factor of one-third to the projected 500 MW thermal output of ITER, and from that he concludes that ITER would generate a gross output of approximately 170 MW of electricity (MWe). He then says that the 50 MW heating input would require 150 MW of electrical power, leaving "virtually nothing for the power grid." Manheimer's calculation would mean a net electrical output of about 20 MWe.

Manheimer, however, doesn't account for the net plant power drain—known as the balance of plant—which is at least 150 MWe. That value includes such power drains as liquid-helium refrigerators, water pumps, and vacuum pumps. When one includes the injected heating power and the plant power drains, a reactor designed like ITER would result in a net loss of 80 MWe, at best.

ITER was never designed to provide net electricity or net thermal power across the entire reactor. Instead, it was designed only to generate net thermal power across the plasma. But in its public communications, the ITER organization until only recently did a poor job of communicating that distinction. That led to, as it did with Manheimer, the common misunderstanding about the expected power balance for ITER. That misconception does not account for at least half of the expected input power.

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Correction

December 2022, page 23—The image caption should read, "Stargazing events such as this one from 27 August at Moʻokini Heiau, a National Historic Landmark on the island of Hawaii, are among the activities that the Thirty Meter Telescope outreach team is collaborating on with Native Hawaiians in efforts to build positive long-term relationships." The credit should read "ʻOhana Kilo Hōkū/Keith Uehara." PT