and these topics are included along with open hardware.

Arancio and Dosemagen emphasize that open science hardware has "enormous potential," in that it "can foster mission-oriented, multiscale collaborations among academia, civil society, governments, and industry," but note that the barriers are significant too. As they outline, policy support is needed, not just to support the creation and use of open science hardware, but to address the questions that come along with it—questions that are central to science itself, but that open science hardware brings into fuller view. As a few of many examples: Who decides what tools and data can be used for research, and how? What will foster public trust in science? How should institutions engage with people that use science to address questions on their own terms?

Public policy communities are circling around this conversation, but it hasn't quite found its home in government. We wouldn't expect the phrase "open science hardware" to mean much (for example) to a scientist at the Environmental Protection Agency interpreting data from an air-quality sensor, or to a program officer in one of the National Science Foundation's science and engineering directorates. "Open hardware" as a label—for both a set of tools and an approach to tool development and use—is too abstract and doesn't quite do it justice. As with many topics in science policy, figuring out how to talk about it is essential, and should be a next step.

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UPDATING THE SOCIAL COST OF CARBON

In addressing efforts to estimate the benefits of combating climate change, David Simpson's article asks in its title, "How Do We Price an Unknowable Risk?" (*Issues*, Winter 2022). To be fair,

Mathemalchemy

What happens when a fiber artist meets a world-renowned mathematician? In a word: *mathemalchemy*.

In 2019, the mathematician Ingrid Daubechies, who the *New York Times* dubbed the "godmother of the digital age" because of her work with wavelets and the role that it played in the advancement of image compression technology, visited an art exhibit entitled *Time to Break Free*. The installation, a quilted, steampunk-inspired sculpture full of fantastical, transformative imagery, was the work of fiber artist Dominique Ehrmann. Seeing the installation made Ingrid wonder whether art could similarly bring the beauty and creativity of mathematics to life. She contacted Dominique, and after much discussion, a collaborative project was born. Over several months, many workshops, and the challenges of a pandemic, the collaborative grew to include 24 core "mathemalchemists" representing a diverse spectrum of expertise. The result is a sensory-rich installation full of fantasy, mathematical history, theorems, illuminating stories of complexity, and even a chipmunk or two.

The artists and mathematicians work in fabric, yarn and string, metal, glass, paper, ceramic, wood, printed plastic, and light; they depict or employ mathematical concepts such as symmetry, topology, optimization, tessellations, fractals, hyperbolic plane, and stereographic projection. Playful constructs include a flurry of Koch snowflakes, Riemann basalt cliffs, and Lebesgue terraces, all named after mathematicians. Additionally, the exhibition pays homage to mathematicians and mathematical ideas from many different origins and backgrounds, ranging from amateur mathematician Marjorie Rice to Fields Medalist and National Academy of Sciences member Maryam Mirzakhani.

Mathemalchemy is on display at the National Academy of Sciences in Washington, DC, from January 24 through June 13, 2022. More information about the exhibit and the collaboration can be found at mathemalchemy.org.

Images courtesy of the artists and Cultural Programs of the National Academy of Sciences; photographs by Kevin Allen.

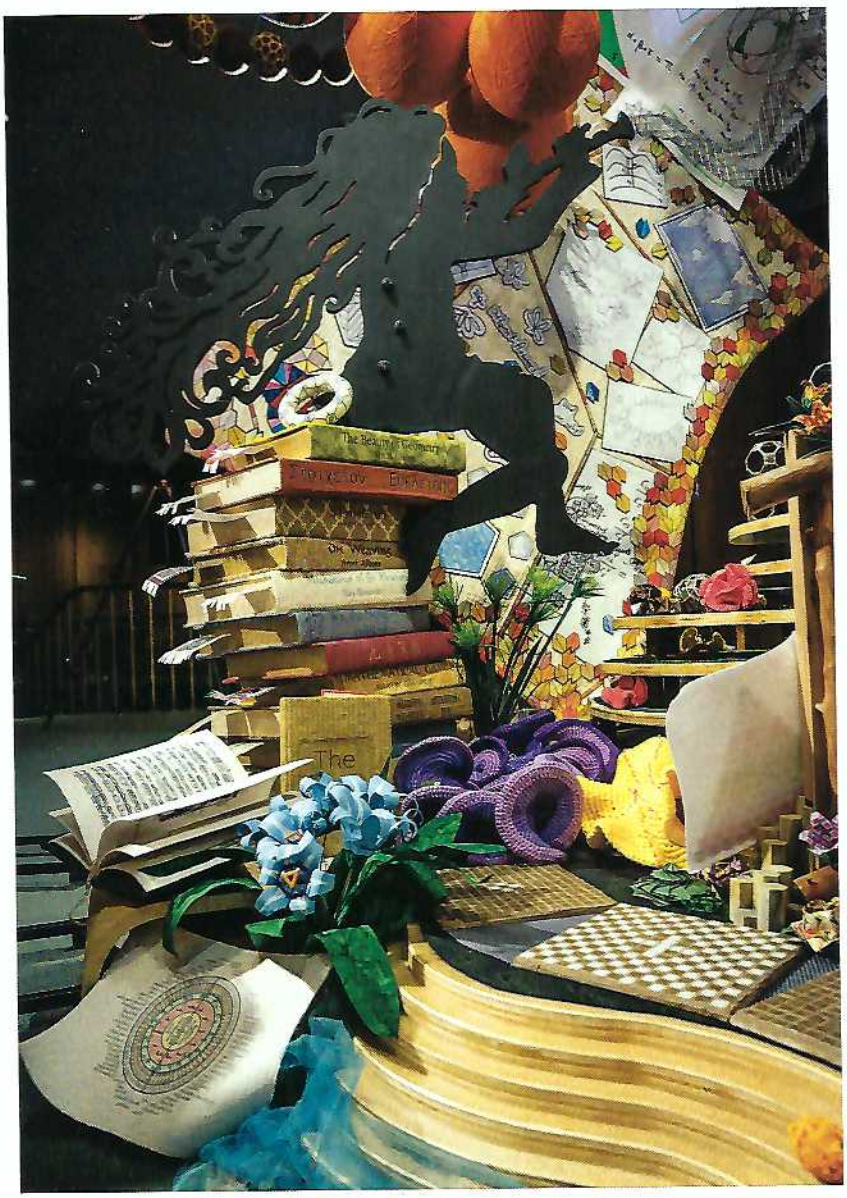
Mathemalchemy, 2021, mixed media

many dimensions of climate change risks are understood, subject to uncertainty, including economic damages. For example, refer to the Intergovernmental Panel on Climate Change's recent 3,600+ page report.

The impressive advances in the damages literature over the past decade enable a rigorous updating of the social cost of carbon (SCC)—the monetized damages associated with another ton of carbon dioxide emissions—used to inform assessments of federal regulations. These assessments show whether the benefits of a regulatory action justify their costs. This is analogous to a business deciding whether a new investment will yield returns in excess of its costs, and to a household weighing the lists of pros and cons in making a decision.

Despite a rich understanding of climate impacts, Simpson claims that the "unknown and unknowable risks of climate change argue for caution" as an alternative to SCC-informed policies. But what is "caution"-based policy? The precautionary principle may sound appealing, but that's because it can have different meanings for different people. Operationalizing the concept quickly becomes ambiguous and political, resulting in different applications and outcomes in different contexts. Under the precautionary principle, an opaque political benefit-cost analysis often substitutes for a transparent regulatory analysis that draws from tools and insights among multiple disciplines' peer-reviewed literatures.

Another alternative that Simpson discusses—estimating a target-consistent price trajectory that represents the least-



cost attainment of a specified long-term emissions target—likewise suffers from political shortcomings. First, it focuses exclusively on costs in how it frames the environmental objective. By making costs so transparent in policy implementation without any accounting or presentation of benefits, this framing could reduce public support for climate policy.

Second, the starting point of this approach is the political decision of an emissions target level and year. Then, this approach requires an assumed set of policies that deliver the carbon price trajectory through its target year. In effect, the target-consistent price relies on political decisions about goals and the means to achieve them, not science. This stands in sharp contrast to the approach of the SCC, that starts by integrating scientific understanding of the impacts of adding more greenhouse gasses to the atmosphere. Indeed, the real-world experience with such a target-consistent price shows how arbitrary political decisions can influence the price path. In 2008, the United Kingdom employed this approach for an 80% reduction target and assumed that the target would be met by purchasing lower-cost emission reductions from other countries.

The decarbonization of the modern global economy will represent one of the most profound transformations of economic activity in history. Policymakers driving such a change will make better decisions (getting the job done through a wise use of resources) and tell a more compelling story (the benefits of these ambitious actions justify their costs) through the use of the social cost of carbon.

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ENERGY FOR GROWTH

In "Fixing the Disconnect Around Energy Access" (*Issues*, Winter 2022), Michael Dioha, Norbert Edomah, and Ken Caldeira contrast the tale of two communities in Nigeria to highlight the daunting challenge of bringing universal energy access to low-income countries in a financially sustainable way. Although the article focuses on two communities in Nigeria, it speaks to a broader issue across the African continent.

In a recent World Bank book that I coauthored, *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact,* we addressed this very issue and laid out ways to think about electrification in sub-Saharan Africa. We reported an example similar to that of Kigbe, one of the authors' case studies. In this case, the community of Gabbar, Senegal, implemented an off-grid solar energy system to help in producing onions for export to cities across the country. Elsewhere, we have also seen financially strained communities trying to get off a $7 per month installment contract they signed to acquire a solar home system—only to realize that they cannot afford the cost a few months down the road.

We also argued, as do Dioha and coauthors, that all electrification efforts should start with viewing it as a means