

Reaching negative CO₂ emissions

David Kramer's article "Negative carbon dioxide emissions" (PHYSICS TODAY, January 2020, page 44) provides an excellent overview of the pros and cons of several climate-ameliorating interventions in the global carbon cycle. But it overlooks what ought to be at the top of our list: protection of natural carbon sinks.

Over the past decade, natural sinks have removed from the atmosphere about 5 gigatons of carbon per year, with approximately three-fifths going to the oceans and the rest to terrestrial ecosystems. That removal rate is about one-half of annual anthropogenic emissions worldwide. And nature does it for free!

That natural sink strength is far greater and far cheaper than any engineered scheme can promise to deliver over the coming two or three decades. If the strength is maintained, a 50% reduction in today's emissions would stabilize atmospheric carbon dioxide; with a fur-

ther reduction in emissions, atmospheric levels would decline over time, albeit at an ever-decreasing rate.

Unfortunately, natural sinks are threatened today by a combination of deforestation, soil erosion, ocean acidification, agricultural malpractices on prime land, increasing exploitation of poorer quality lands for food production, and climate change itself. Yet on farmland, protection and augmentation of natural sinks can even increase crop yields.

The most important thing we can do to sequester carbon is to prevent the degradation of existing, priceless, and cost-free natural sinks. Combined with rapid deployment of renewable energy, they might give us a chance to prevent climate catastrophe.

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I appreciate David Kramer's informative article "Negative carbon dioxide emissions" (PHYSICS TODAY, January 2020, page 44). It appears that negative emission technology (NET) will be needed. However, I am puzzled by one phrase—"achieving Paris goals without retarding economic growth." Isn't it obvious that perpetual economic growth in our finite terrarium/aquarium is not possible? Long-time PHYSICS TODAY readers will remember several items by Albert Bartlett about exponential growth (see, for example, PHYSICS TODAY, July 2004, page 53, and March 1994, page 92). Such growth—economic and other—is a primary driver of increasing carbon dioxide emissions and thus of climate change.

Kramer quotes Julio Friedmann: "We have to create an industry the size of the oil and gas industry that runs in reverse." The oil and gas industry generates its output to make a profit. The "reverse output" of the NET industry—tens of gigatons of CO₂ sequestered annually—is not a marketable product to be sold for up to \$100 per ton. A carbon fee may be needed to fund NET.

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Would use of CO₂ for enhanced recovery of oil make up any significant fraction of tens of gigatons per year? How much CO₂ would be released in burning the additional oil produced? Does the CO₂ come back up with the oil? Then what?

Kramer mentions “improved forest management” but doesn’t explain it. In the western US, politicians and others often use that phrase as code for “more logging.” (They usually avoid the word “logging” in favor of “thinning,” “forest health,” or similar language.) A purported goal is to reduce the fuel available to forest fires. Proposals to increase CO₂ storage by reforestation and large-scale tree planting on public land are incompatible with demands for forest-fire fuel reduction. Studies by wildfire scientists and ecologists^{1,2} show that such fuel reduction is generally ineffective in reducing large fires and is ecologically damaging. It is not improved management.

References

1. D. A. DellaSala, testimony before the US House Natural Resources Committee, Subcommittee on Oversight and Investigations, 27 September 2017, p. 3.
2. T. Schoennagel et al., *Proc. Natl. Acad. Sci. USA* **114**, 4582 (2017).

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Carbon pricing needs a dividend

Media outlets have emphasized how our changing climate fuels such tragic events as the blazing Australian bushfires in 2019–20. One should also remember that policies can be enacted to address the daunting challenge of climate change. David Kramer’s story “Should carbon emissions be taxed or capped and traded?” (*PHYSICS TODAY*, December 2019, page 28) provides a timely comparison of market-based policies aimed at reducing greenhouse gas emissions. One approach that is catching unprecedented attention among economists and members of the US Congress is a carbon fee coupled with a dividend.

I think about the economics of carbon pricing in terms of uncertainty. In physics,

we are used to thinking of trade-offs in uncertainty when measuring conjugate variables such as position and momentum. Economists inevitably trade off uncertainty in price and quantity when designing carbon-pricing policies; a carbon fee addresses the former, and cap and trade the latter. The distinction may sound pedantic, but it matters when courting stakeholders.

Ensuring certainty in carbon’s price is a practical political move. Although we must reduce our carbon emissions, the exact quantity of that reduction can afford some uncertainty. The benefit of fixing carbon’s price is the ability to minimize economic risk,¹ a choice that businesses generally prefer. Under the carbon fee policy, a fixed fee is charged for each ton of emitted carbon dioxide and is gradually increased each year.

Kramer’s story briefly mentions what might happen to the revenue generated from the carbon fee. Should it be used at the government’s discretion or returned as an equal dividend to each citizen?

Incidents of resistance to carbon pricing point to the need for a dividend. Kramer cites the French yellow vest protests as an example of how a faulty policy can cause social unrest. But the crucial lesson is that any carbon-pricing policy must adequately address economic inequality. By returning a dividend equally to all taxpayers, the policy becomes overall progressive and effectively revenue neutral—a more politically viable option in line with a conservative desire for limited government.

Economists are in nearly universal agreement that carbon pricing is best accompanied by a dividend. A historic statement published in the *Wall Street Journal*² made the consensus explicit. Among the signatories are 27 Nobel laureates, 4 former chairs of the Federal Reserve, and more than 3500 US economists.

Beyond that remarkable level of unity among economists, more than half a dozen carbon-pricing bills were introduced in Congress last year. The one with the most congressional cosponsors, by about an order of magnitude, is the Energy Innovation and Carbon Dividend Act of 2019 (HR 763). Last October Columbia University’s Center on Global Energy Policy released an assessment of HR 763 that projects emissions reductions by 2030 will “exceed the US commitments

to the Paris Agreement” and that the “substantial revenue” returned as a dividend will generally benefit low- and middle-income households more than the fee hurts them.³

Despite growing support for the bill, I sympathize with Kramer’s concern regarding “today’s polarized US political climate” and the likelihood of opposition to carbon pricing. But I have found that participating in our democracy is an antidote to that pessimistic outlook. Passing national carbon-pricing legislation requires a sufficient level of political will, which we create by asking our elected representatives to support HR 763.

References

1. C. Hepburn, *Oxf. Rev. Econ. Policy* **22**, 226 (2006).
2. “Economists’ statement on carbon dividends,” *Wall Street Journal*, 16 January 2019.
3. N. Kaufman, J. Larsen, P. Marsters, H. Kolus, S. Mohan, *An Assessment of the Energy Innovation and Carbon Dividend Act*, Columbia University (2019).

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Time, the revelator

I am now retired, but throughout my career as a professor I consistently argued that student opinion forms collected in the last week of a course were nearly useless for the evaluation or improvement of teaching effectiveness, though the free-form comments were occasionally useful or at least amusing. I was surprised that an ideal mechanism to evaluate teaching—which I’ve championed for at least 25 years—was not included in Toni Feder’s article “Reevaluating teacher evaluations in higher education” (*PHYSICS TODAY*, January 2020, page 24).

Technology has made it simple to keep track of students who took a particular class and to send them an email questionnaire about it a few years later. Did that course have a positive effect on their education—for example, on their preparedness for subsequent courses—or on their careers? Answers to questions like the following would help make that determination: