community at Mount Holyoke College in *Defining Women's Scientific Enterprise*.[2]

This is not to say that female physicists in the US didn't face plenty of barriers as well—they certainly did! Rather, it is a telling confirmation of how contextual and changeable culture is.

References

1. P. Fara, *A Lab of One's Own: Science and Suffrage in the First World War*, Oxford U. Press (2018).
2. M. R. Levin, *Defining Women's Scientific Enterprise: Mount Holyoke Faculty and the Rise of American Science*, U. Press New England (2005).

Joanna Behrman
(jbehrman@aip.org)
American Institute of Physics
College Park, Maryland

Hope for CO_2 air capture

John Tanner's summary of carbon dioxide air-capture costs (Physics Today, February 2023, page 12) takes the glass-half-empty approach to an extreme. At the average US retail price for electricity (12¢/kWh), the thermodynamic energy demand of direct air capture[1] would indeed add $15 to the cost of collecting a metric ton of CO_2 from air. But large power consumers, such as aluminum smelters, get much better pricing.[2]

Moreover, removing 8 billion metric tons of CO_2 for a mere $120 billion would be a good deal. It would cancel past emissions from about 20 billion barrels of oil. The world buys that much oil every 200 days for $1.6 trillion. Prices for such a quantity have fluctuated between $200 billion and $3 trillion over the years. The implied surcharge of $6 per barrel seems cheap for fixing the climate.

Can air capture achieve such economics? The bad news is that current costs are above $500 per metric ton of CO_2. I agree with Tanner that thermodynamic limits plus unavoidable raw-material inputs set a lower bound around $10–$20 per metric ton.[3] The good news is that no physical law prevents approaching that bound through learning by doing. Betting against an order-of-magnitude cost reduction ignores the two-orders-of-magnitude reduction in wind and solar. It collides with the frequently expressed optimism that batteries will get cheaper if we produce a lot of them. Mass production has proven over and over that costs can drop 10-fold if cumulative capacity increases 1000-fold.[4] For air capture, which needs to grow more than a millionfold, that represents just the beginning of the growth curve.[5] Obviously, success is not guaranteed, but closing the door to the opportunity without trying is self-defeating.

References

1. K. S. Lackner, *Energy* **50**, 38 (2013).
2. See, for instance, "Power costs in the production of primary aluminum," MetalMiner, 26 February 2009, reposted 24 November 2015, https://agmetalminer.com/?s = power+costs.
3. K. Lackner, H.-J. Ziock, P. Grimes, *Carbon Dioxide Extraction from Air: Is It an Option?*, rep. no. LA-UR-99-583, US Department of Energy (1 February 1999).
4. E. Dahlgren et al., *Eng. Econ.* **58**, 231 (2013).
5. K. S. Lackner, H. Azarabadi, *Ind. Eng. Chem. Res.* **60**, 8196 (2021).

Klaus S. Lackner
(klaus.lackner@asu.edu)
Arizona State University
Tempe