LETTER

# Reply to Schuiling: Last things last

Schuiling's letter (1) concerning my commentary on geoengineering (2) makes two major claims: (*i*) decarbonization of the global industrial metabolism is not driven by climate protection but by the exhaustion dynamics of fossil fuels, and (*ii*) there is an attractive option for artificial $CO_2$ removal from the atmosphere, namely, milling of olivine-rich rocks.

However, Schuiling (1) is too pessimistic regarding the first point and too optimistic regarding the second one. To begin with, the aphorism that "the stone age was not terminated by the depletion of stones" (Ahmed Yamani) also applies to the contemporary climate–energy challenge: An incumbent technical culture is replaced if there is a superior alternative in terms of externalities and intrinsic performance. For instance, Germany's recent decision to switch to an efficient-renewable energy system by 2050 is driven by environmental goals (confining global warming) and economic considerations (securing affordable energy supply). Topical cost estimates actually confirm that onshore wind power is already on a par with conventional power generation, whereas photovoltaic power will reach parity very soon. These pioneering lessons are crucial for the emerging economies in China, India, and Brazil, which can go for the double-dividend accruing from the renewables revolution instead of duplicating the "black" development story of the West.

As for the geoengineering potential of enhanced olivine weathering, the jury is still out. A recent assessment of "direct air capture of $CO_2$ with chemicals" by the American Physical Society (3) is in broad agreement with the rather discouraging findings of House et al. (4). The American Physical Society report only acknowledges the suggestion to disseminate milled olivine in tropical catchments. Köhler et al. (5) have taken a closer look at that scheme and identify sobering upper bounds for the resulting carbon extraction as well as major environmental side effects like river acidification. The authors concede that more research is needed for arriving at robust conclusions. The same caveat applies, however, to Schuiling's stunning cost estimate (just US $10 for 1 ton of $CO_2$ sequestered) (1). This obviously does not account for ecological externalities, let alone for the total systems cost of handling several gigatonnes (Gt) of material per annum.

Nevertheless, Schuiling's approach (1) is one of the very few macroengineering schemes that deserve to be further explored. But, I have to reiterate my warning against the wrong timing of climate-protection measures and, even more importantly, against the wrong signals in terms of political psychology (2): Barring technological miracles, air capture of $CO_2$ will not become a silver bullet, but perhaps it may become one grain of silver buckshot for getting rid of some 50 Gt of carbon dioxide each year. On the other hand, geoengineering speculations may prove counterproductive by delaying bulk-decarbonization steps like energy-efficiency enhancement. The latter depends heavily on slow variables like market structures and behavioral patterns. Therefore, embarking on the avenue toward low-carbon prosperity is the top priority. By way of contrast, recapturing $CO_2$ can wait until adequate research and development investments have considerably improved nascent schemes: last things last.

***Hans Joachim Schellnhuber***[1]
*Potsdam Institute for Climate Impact Research, D-14412 Potsdam, Germany*

1. Schuiling RD (2012) Capturing $CO_2$ from air. *Proc Natl Acad Sci USA* 109:E1210.
2. Schellnhuber HJ (2011) Geoengineering: The good, the MAD, and the sensible. *Proc Natl Acad Sci USA* 108:20277–20278.
3. American Physical Society (2011) Direct Air Capture of $CO_2$ with Chemicals (Technology Assessment).
4. House KZ, et al. (2011) Economic and energetic analysis of capturing $CO_2$ from ambient air. *Proc Natl Acad Sci USA* 108:20428–20433.
5. Köhler PJ, Hartmann J, Wolf-Gladrow DA (2010) Geoengineering potential of artificially enhanced silicate weathering of olivine. *Proc Natl Acad Sci USA* 107:20228–20233.

Author contributions: H.J.S. wrote the paper.

The author declares no conflict of interest.

[1]E-mail: john@pik-potsdam.de.