Why we need the 'and' in 'CO_2 utilization and storage'

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While research is still needed to answer scientific and technical questions about CO_2 Capture and Storage (CCS), it is largely economic and political forces rather than technical issues that have prevented widespread deployment of CCS over the last decade. Meanwhile, the energy-climate crisis continues as fossil-fuel use grows, causing atmospheric concentrations of CO_2 to increase, along with global atmospheric temperatures and the associated measurable and costly impacts on Earth's climate. Given the current economic and political state of affairs, it is natural to look for ways other than storage (seques- tration) by which mankind can decrease greenhouse gas (GHG) emissions. With CO_2 accounting for approximately 70% of the GHG radiative forcing from among the other main GHGs (CH_4, N_2O, CF_4, C_2F_6, SF_6, and HFC-23, 134a, and 152a), and with abundant fossil-fuel-combustion point sources of CO_2 available, it makes sense to focus on reducing net emissions of CO_2 by any and all means.

With direct injection into the ground for permanent sequestration currently considered expensive and lacking popular support, many people concerned about energy and climate have turned to studying utilization of CO_2 – so-called CO_2 Capture, Utilization, and Storage (CCUS). In fact, the annual CCS confer- ence held for several years now in Pittsburgh changed its name this year to the 11th Annual Conference on Carbon Capture Utilization & Sequestration. Currently, CO_2 is used beneficially for a large number of purposes in the chemical, pharmaceutical, food and beverage, agricultural, healthcare, environ- mental, energy resource extraction, pulp and paper, electronic, metals, and fire safety industries .[1,2] In the area of energy resource extraction, the oil industry injects millions of tonnes of CO_2 per year for enhanced oil recovery (CO_2 - EOR). While much of the current utilization demand makes use of CO_2 as is, vast amounts of CO_2 are also converted into a variety of useful products such as urea (fertilizer), formic acid (preservative for animal feed), and syngas (fuel). Although there exist many potential large-scale uses for CO_2, the current demand is dwarfed by the potential supply from anthropogenic sources (mostly fossil fuel combustion), and projections of increased fossil-fuel use make it difficult to envision utilization ever solving the energy-climate crisis. For example, Song[3] estimated the total potential US demand for CO_2 in the chemical and materials industries at approximately 6 MtCO_2/yr, approximately the output of a 750 MW coal- fired power plant. CO_2-EOR within the USA currently uses a lot more CO_2 than do the chemical and material industries, approximately 48 Mt CO_2/yr,[3] or the output of six 1-GW coal-fired power plants. Urea production in the USA is the largest single use at 120 Mt CO_2/yr.[2] Meanwhile, the current US power plant CO_2 emissions are estimated to be about 3 Gt CO_2/yr, or about 15 times larger than the current US utilization rate of approximately 200 Mt CO_2/yr. Moreover, it deserves mention here that the vast majority of CO_2 used for EOR comes from natural CO_2 reservoirs rather than anthropogenic sources. While we can envision policies arising from concern for climate that will motivate greater utilization of anthropogenic CO_2, this greater utilization rate will occur in a future with potentially much larger rates of CO_2 emissions, assuming that global projections of increased de- mand for energy and its modes of generation are correct.

Despite the raw numbers and what they reveal about the imbalance between today's CO_2 utilization and anthropo- genic emissions, increasing CO_2 utilization is still a worthy goal. The fact is we need to start reducing CO_2 emis- sions in every way we can. The problem of global anthropogenic GHG emissions of approximately 30 Gt CO_2/yr is so large that it demands solutions from every corner of Earth. For example, off-setting electricity production from coal by greater use of nuclear and renewable energy sources is an effective CO_2 emissions mitigation strategy, but utilization can potentially reduce CO_2 emissions even more than these fuel-substitution approaches.[4] And there is hope for large increases in utilization. First, increased application of CO_2-EOR, along with a large-scale switchover to anthropogenic

sources of CO_2 used for EOR, could drastically increase that sector's efficacy in reducing anthro- pogenic emissions. In addition, there are new sectors being studied, such as the use of CO_2 as a cushion gas for energy storage.[5] Granted, if our energy supply remains dominated by fossil fuels used as they are today, even these relatively large sub-surface uses will remain dwarfed by combustion-related emissions. But there are also promising demonstrations of the use of CO_2 in making cement,[6] a potentially game-changing approach given the vast and growing 3.3 Gt/yr global market for cement used in concrete. Related approaches to carbonation and mineralization for CCS were presented in the last issue of Volume 1 of this journal (see Zevenhoven[7] for an overview).

So while utilization will not contribute a large amount to reducing anthropogenic CO_2 emissions in the near future, it remains a critically important area, because it does not rely solely on policy decisions that can be influenced by a fickle economy. Rather, it relies on technological breakthroughs and market competitiveness. That is not to say that policies cannot help increase the scale of utilization, but rather that CO_2 utilization can stand on its own, as demonstrated by the wide variety of current uses. While increased research and publication emphasis on utilization is welcomed (e.g., through publications in this journal), we need to remember that the large long-term potential mitigation of CO_2 emissions provided by underground CO_2 storage[8] will be needed as long as fossil fuels are used as they are today, requiring that we keep the 'and' in 'utilization and storage'.

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