

Abstract

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The energy requirements of carbon dioxide utilization (CDU) technologies/processes are diverse, so also are their environmental footprints. This paper explores the energy and environmental impacts of systems for CO₂ conversion to fuels, chemicals and materials. Energy needs of the technologies and processes deployable in CO₂ conversion systems are met by one or combinations of hydrogen (chemical), electricity, heat, and light. Likewise, the environmental footprint of any CO₂ utilization pathway depends on the systems involved. So far, evaluation of CDU systems have been constrained to particular energy source/type or a subset of the overall system needed to make CDU possible. This introduces limitations to the general understanding of the energy and environmental implications of CDU, leading to various pitfalls in past studies. A CDU system has an energy source, CO₂ supply and conversion units. We apply a holistic approach to consider the impacts of all components in the process, including various sources of energy, CO₂ feedstock, and conversion technologies. The electricity sources include nuclear power, renewables (wind and solar PV), gas turbine, and coal. Heat is supplied from either electricity or natural gas, and hydrogen is produced from either steam methane reforming or electrolysis. The CO₂ capture unit uses either direct air capture or post-combustion capture via amine scrubbing. Where applicable, integrated configurations of the CDU system are explored. We demonstrate how the overall energy and environmental impacts of each utilization pathway is obtained by aggregating the values for all components involved. Proper accounting of the energy and emission intensities of CDU must incorporate total balances for the utilization process and differences in timescales between alternative conversion pathways. Our results highlight opportunities for the use of clean energy sources, direct air capture, and a number of promising CO₂ conversion pathways for producing methanol, ethanol, formic acid, synfuel and polymer materials.