World Academy of Science, Engineering and Technology
International Journal of Mathematical and Computational Sciences
Vol:14, No:12, 2020

Energy Options and Environmental Impacts of Carbon Dioxide Utilization Pathways

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Abstract : 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 CO_2 conversion to fuels, chemicals, and materials. Energy needs of the technologies and processes deployable in CO_2 conversion systems are met by one or combinations of hydrogen (chemical), electricity, heat, and light. Likewise, the environmental footprint of any CO_2 utilization pathway depends on the systems involved. So far, evaluation of CDU systems has 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, which has led to various pitfalls in past studies. A CDU system has an energy source, CO_2 supply, and conversion units. We apply a holistic approach to consider the impacts of all components in the process, including various sources of energy, CO_2 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 CO_2 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 are 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 CO_2 conversion pathways for producing methanol, ethanol, synfuel, urea, and polymer materials.

Keywords : carbon dioxide utilization, processes, energy options, environmental impacts
Conference Title : ICSRD 2020 : International Conference on Scientific Research and Development
Conference Location : Chicago, United States
Conference Dates : December 12-13, 2020