Greenhouse Gas Emissions Life Cycle Analysis of Carbon Capture and Storage for Industrial Sources in the Midwest Regional Carbon Initiative

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Background/Objectives. Many industrial sources of greenhouse gas emissions are considering carbon capture and storage (CCS) to reduce emissions. In terms of life cycle analysis of greenhouse gas emissions, CCS operations have several components that may produce emissions including CO_2 capture/separation, facility construction, CO_2 compression, CO_2 purification/dehydration, pipeline transport, injection well drilling, fugitive emissions, pipeline construction, land use, venting/flaring of process gases, and embodied emissions for materials (API, 2009; DOE-NETL, 2015; Skone, 2015). The emissions related to CCS operations may offset the CO_2 stored in geological formations. Consequently, life cycle analysis of net CO_2 storage considering the operational emissions is useful to support development of CCS in the Midwest Regional Carbon Initiative (MRCI), which has the objective to accelerate CCS in 20 states in the Midwest-Northeast U.S.

Greenhouse gases generated for CO_2 point source facilities in the Midwest-Northeast region of the United States were evaluated to account for “cradle to grave” CO_2 equivalent emissions for carbon capture, compression, transport, and storage in relation to volumes of CO_2 stored underground. There were three objectives of the study: 1) evaluate greenhouse gases generated for CCUS facilities in the MRCI region, 2) account for “cradle to grave” CO_2 equivalent (CO_2e) emissions for carbon capture, transport, and storage in relation to volume of CO_2 stored underground, and 3) integrate MRCI specific factors on CO_2 sources, geology, and geographic location. The end product of the study was greenhouse gas life cycle guidance for developing CCS in the MRCI region in terms of maximizing net CO_2 storage effectiveness. Optimizing decarbonization of these large point sources of greenhouse gases will help facilitate climate resilience in this key industrial corridor of the U.S.

Approach/Activities. Eight scenarios were assessed in the study: ethanol plant, natural gas power plant, direct air capture plant, CO_2 enhanced oil recovery, hydrogen plant, petroleum refinery, cement plant, and fertilizer/ammonia plant. These sources reflect industry in the region that may be considering carbon capture and storage. The analysis integrated specific factors for CO_2 sources in the region, including geologic storage setting, geographic location, CO_2 emission volumes, capture requirements, compression, CO_2 transport, and injection. A greenhouse gas life cycle analysis model was applied for CCUS operations that may contribute to greenhouse gas emissions (Azzolina, 2016; Sminchak, 2020). As with any life cycle analysis, the boundaries of the analysis are important factors. The model included general capture parameters with more detailed parameters for CO_2 compression, transport, and injection. The model did not account for combustion of fuel products or displaced electricity.

Key input for the greenhouse gas emissions life cycle analysis included the following items: source size (based on existing sources in MRCI), energy for capture, compression requirements, pipeline transport distances, and fugitive emissions. Scenarios were evaluated for low, average, and high source emissions. The life cycle model includes more than 200 other input parameters that account for items like fugitive emissions, construction, land displacement, energy for compression, energy for capture, flaring, facility electricity, and many other emission items.

Results/Lessons Learned. Results of the life cycle analysis suggest that net carbon storage for sources may vary from 59 to 91%. Results reflect net CO_2 stored versus emissions generated from capture, compression, transport, and injection. Also, economies of scale can affect net storage, because smaller sources will require moderate construction regardless of source size. Sources that integrate capture and compression such as hydrogen plants and ammonia plants have highest net storage. Since there are no direct air capture plants in this region, the source information and life cycle process information were based on technical articles on the development of direct area capture. It was not possible to evaluate emissions from refineries, because they include so many different sources of emissions.

The greenhouse gas life cycle analysis provides insight into developing CCUS in the region in terms of net CO_2 storage versus the emissions related to facility operations. Emissions generated by CO_2 compression, transport, and injection may counter the carbon storage mass for smaller CO_2 sources, especially in areas where geologic CO_2 storage options are not readily accessible. Therefore, greenhouse gas emissions life cycle analysis is useful in ensuring maximum, net CO_2 storage for development of CCUS facilities in the Midwest-Northeast United States. As with any life cycle analysis, it is difficult to account for all of the emission factors related to CCS operations. A life cycle analysis based on actual operational records over many years would be a more accurate depiction of emission balance for a CCS project. However, few CCS operations provide precedent for this analysis. Overall, the greenhouse gas life cycle analysis suggests that it is important to consider the emissions that are generated from CCS operations in addition to the CO_2 storage mass. This work was supported by the Midwest Regional Carbon Initiative (U.S. Department of Energy Award No.: DE-FE0031836).