THE UNIVERSITY OF BRITISH COLUMBIA

PacifiCan-MMRI Accelerating Circular Economy (ACE) TechBrief Report

Materials & Manufacturing Research Institute

Project title: Micro Carbon Capture and Utilization: A Canadian Solution for Low-Carbon Heating with Natural Gas

Industry partner(s): CleanO2, FortisBC, Pacific Northern Gas (an AltaGas subsidiary), ATCO Gas, Northern Lights College, City of Dawson Creek

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Introduction & Background:

In the context of global environmental challenges, the need to alleviate undesired global warming due to the substantial emissions of carbon dioxide (CO2) and other greenhouse gases (GHGs) is significant. Carbon-capturing, utilization, and storage (CCUS) can be perceived as an effective solution to this problem since this would prevent the emission of CO2 into the atmosphere. Buildings occupy a considerable portion of different GHG-emitting sources; in fact, it is estimated that the source of 17% of Canadian GHG emissions is from buildings [1]. Hence, extensive efforts are required to curb GHGs emitted from buildings. Integrating CCUS technologies into new and existing buildings – also termed Micro Carbon Capture and Utilization (MCCU) – can be seen as a prospective building retrofit to decrease GHG emissions from buildings. The technology considered in this study developed by CleanO2 captures CO2 from effluent gas streams using solid potassium hydroxide (KOH) pellets. Potassium carbonate (K2CO3) is generated as a by-product of this process. This technology serves two purposes simultaneously: preventing CO2 from escaping into the atmosphere as well as generating K2CO3 with economic value used in fire suppression, fertilizer production, textile dying and printing, as a pH regulator and buffering agent in the pharmaceutical industry, and as a food additive. This study assessed the feasibility of the above technology by evaluating social, economic, and environmental sustainability and market acceptance. Furthermore, this research developed essential decision-support tools for climate action planning.

Relevance to Circular Economy:

Although carbon-capturing technology reduces emissions from fossil combustion sources at the operational level, it uses raw materials and energy during the operation. On the other hand, It produces by-products that can avoid the production of materials. This comprehensive study has adapted life cycle thinking to thoroughly evaluate the economic and environmental sustainability of MCCU systems considering all project life cycle stages. This ensures that aspects like the circular economy have been taken into account.

Methodology:

The methodology is illustrated in Figure 1. During the initial phase of the project, the technical performance of the MCCU system was evaluated through experimentation of the mass balance. A real-time data monitoring system was developed to measure the heat and mass flow through the system. The findings were used to evaluate the average carbon capture and heat recovery rate of the MCCU system. Life Cycle Assessment and Life Cycle Costing methods were utilized to evaluate the environmental and economic impacts of the technology. The impacts were compared against commercially available emissions-saving technologies. A multi-attribute decision-making-based decision support framework was developed to compare technologies under different stakeholder perspectives. A questionnaire survey-based market analysis was conducted to understand the market acceptance of the technology. Finally, a long-term feasibility assessment framework was developed to understand the technology diffusion considering different aspects such as technology learning rate and different business models. The systems dynamics technique, along with the bass-diffusion model, was used to develop the long-term feasibility assessment model.

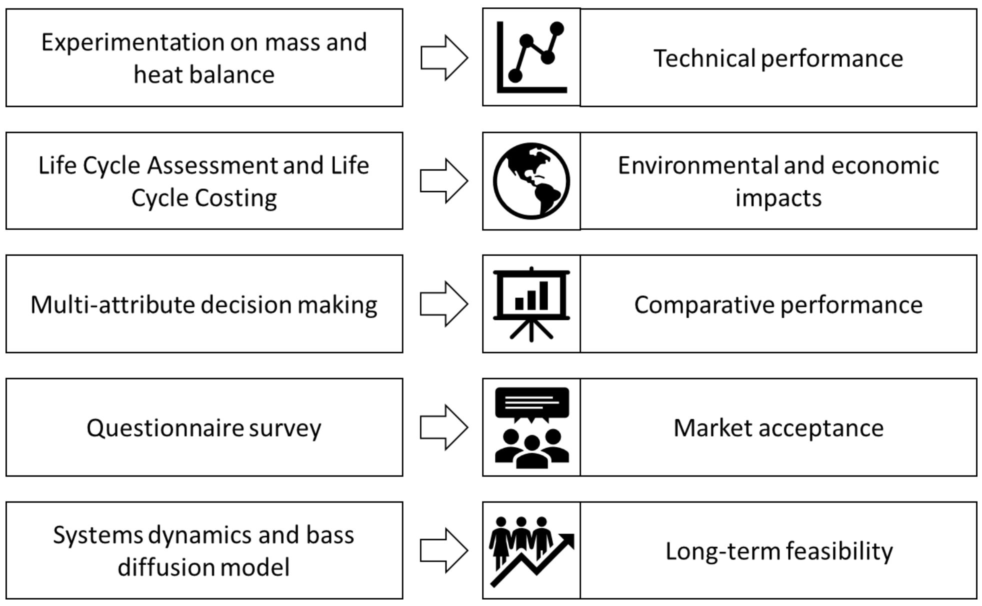

Figure 1: Overall methodology

Results & Discussion

This section presents an environmental and economic analysis of different energy systems applied to a commercial water heating system (Base: natural gas heating system; MCCU BM1: MCCU system with the user-maintain business model; MCCU BM2: MCCU system with the external party-maintain business model; EH: Electric heating system; ASHP: Air-source heat pump; Solar x%: Solar thermal system that covers x% of the heating requirement). The results indicate that The MCCU system reduces the GHG emissions by 18% in AB and 23% in BC with the avoided production of its by-product. Electric heating system has the highest global warming potential in AB due to the fossil fuel-dominant electricity grid. Air-source heat pump has the lowest GHG emissions in BC, which accounts 80% of GHG emissions reduction. The solar thermal system can reduce the GHG emission up to 42% in AB and 45% in BC.

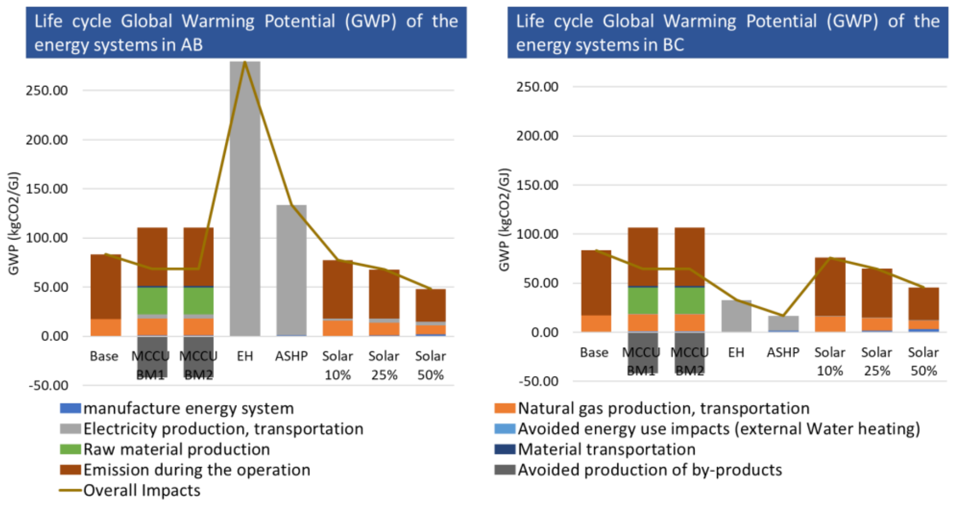

Figure 2: Life cycle GHG emissions of different energy systems

Figure 3 shows the life cycle costs. The MCCU system under the BM2 business model has the lowest life cycle energy cost, which is 9% lower than the base case. The cost of the MCCU system under the BM1 business model is slightly higher than the base case, however, it is lower than the rest of the alternative energy systems. Electric heating systems have the highest life cycle energy cost while air-source heat pumps have the second largest energy cost. The solar thermal system can increase the life cost by 4% - 28% compared to the base case.

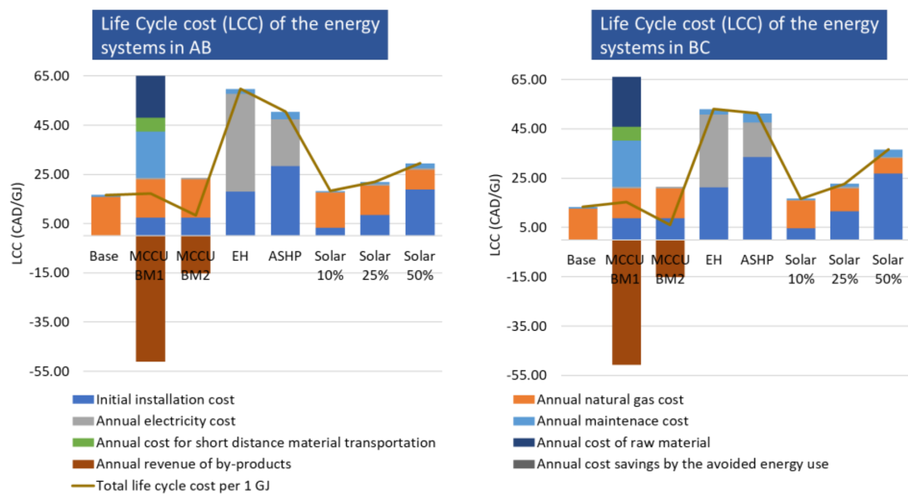

Figure 3: Life cycle GHG emissions of different energy systems

Conclusion & Next Steps

The study shows that the MCCU technology has substantial economic and environmental benefits compared to other technologies. The MCCU can be a cost-effective emission reduction solution, especially in locations with fossil fuel-dependent electricity grids. However, less environmentally beneficial compared to electric and air-source heat pumps installed in locations with renewable energy-based electricity grids. Furthermore, the economic and environmental performance of the MCCU technology depends on the avoided environmental impacts of the conventionally produced by-products. Lower demand for the by-products can increase the cost of the MCCU technology due to the decreased revenue. Further studies are required to assess the long-term feasibility of the MCCU technology, considering the market dynamics and social acceptability.

References.

[1] Liyanage, R., Hewage, K., & Karunathilake, H. (2020). Feasibility study of integrating carbon capturing and utilization in building level natural gas heating systems. 2nd International Conference on New Horizons in Green Civil Engineering 2020.

Funding provided by:

The authors gratefully acknowledge the support provided by the Natural Sciences and Engineering Research Council of Canada (NSERC), CleanO2, and FortisBC.

ACE project funding provided by: Pacific Economic Development Canada, NRC Industrial Research Assistance Program, NSERC CRSNG, Mitacs, The University of British Columbia

Document # MMRI-21022025