Development of a Novel Cross-Current Configuration for Enhanced Syngas Production from Biomass

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Priority topic area: Clean Energy and Climate Action

1 – Motivation

The increased environmental stress due to rising demand for energy and chemicals has necessitated the development of carbon-neutral technologies. Biomass, a low-carbon feedstock, is a promising alternative to fossil fuels, and the chemical looping platform can be leveraged to establish a process for biomass gasification to syngas, a key building block for chemicals. The chemical looping platform utilizes solid oxygen carriers (OC) in a two-step configuration, with advantages such as product separation and operational flexibility.[1] The Ohio State University has licensed a chemical looping technology for biomass gasification. However, this project is part of the effort to further improve the technology.[2]

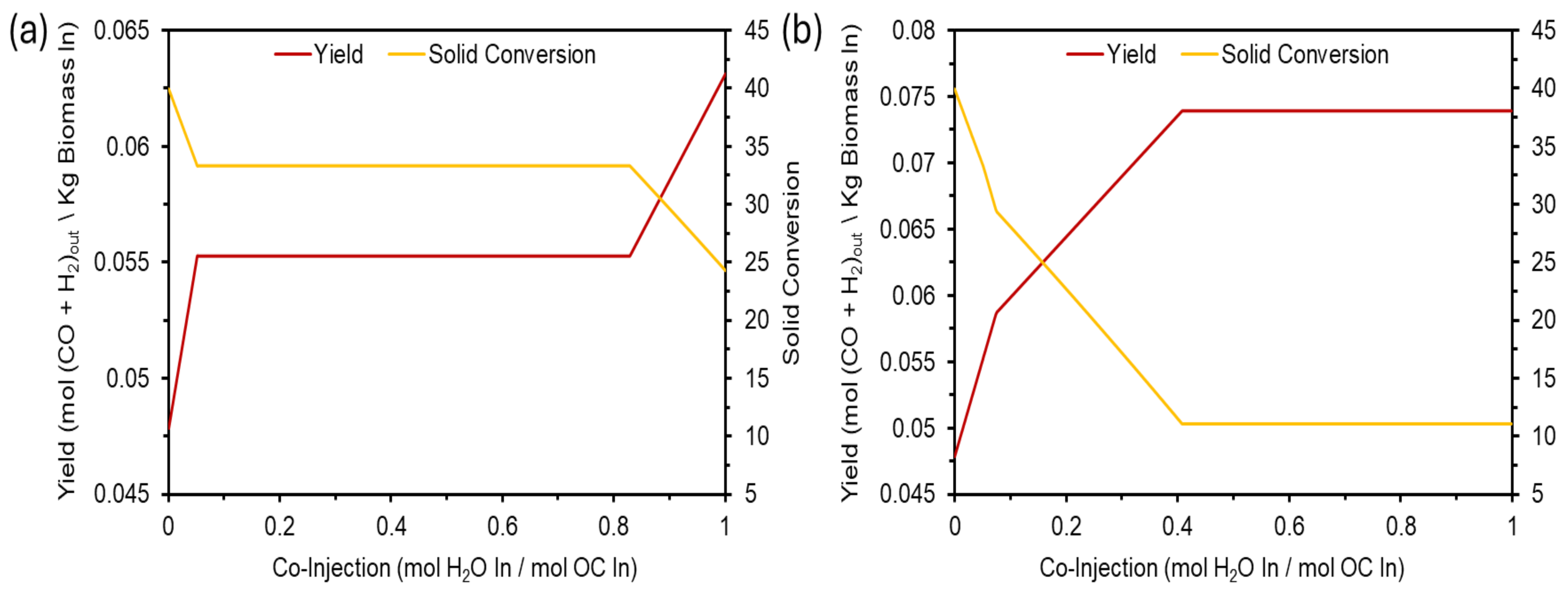

Figure 2: Performance of(a) Co-Current and (b)Cross-Current Reactor Configurations Under Isothermal Condition[3]

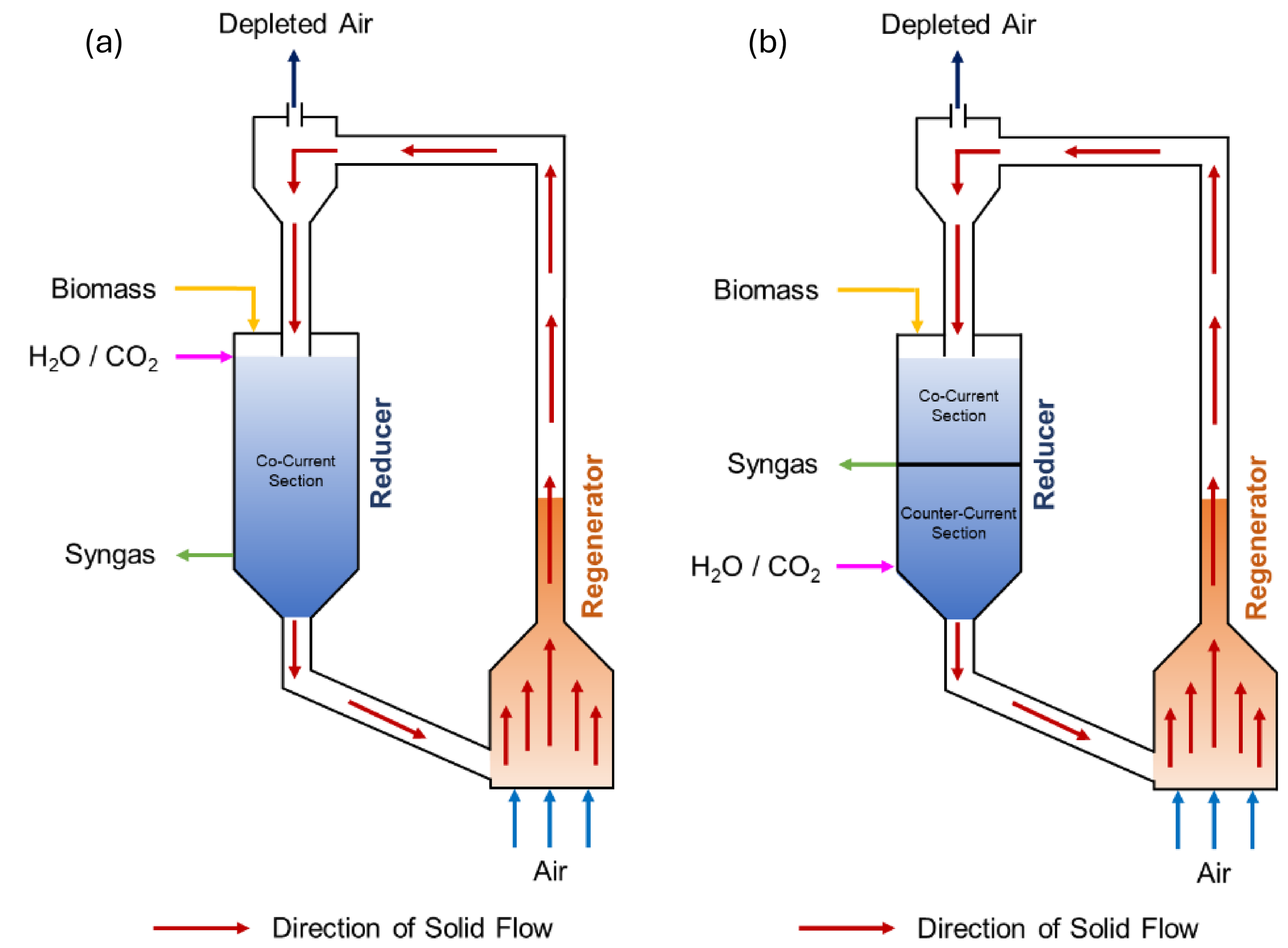

Figure 1: (a) Co-Current and (b) Cross-Current Reactor Configurations[3]

2 – Methodology & Planned Deliverables

The initial technology development focused on autothermal operation, i.e., syngas production from biomass without any external heat supply. However, with increasing research in renewables, a cheap and low-carbon heat supply might be possible, allowing for isothermal operation. **Thus, the focus of the project was to find and ascertain a configuration that would lead to higher syngas yield under isothermal operation with the constraints that no significant changes to the system are possible (i.e., seamless switching between autothermal and isothermal operation modes is feasible).** Under this constraint, the novel cross-current configuration was developed and subsequently modeled in ASPEN.

3 – Project Outputs & Key Findings

Biomass, as it gasifies, splits into volatiles and char. The volatiles react with the carriers while char gasification requires a co-injection of steam or CO2. In the incumbent configuration, termed co-current, the co-injection stream, carriers, and biomass enter from the top of the reactor and exit at the bottom. However, in the novel cross-current configuration, the gas exit is shifted from the bottom to the middle, and the co-injection stream is sent from the bottom, as depicted in Figure 1[3]. **This simple change results in ~34% higher syngas yield under isothermal conditions at lower co-injection flow rate, as seen in Figure 2.**[3] The reason for yield enhancement is revealed by the gas-solid thermodynamics shown in Figure 3. For all starting solid carrier conversion at or below 33.33%, the effect of co-injection is the same for both configurations. However, above 33.33%, a plateau region exists for co-current, which is not present in the cross-current, enabling higher yield. This higher yield is only possible in isothermal operation, as for autothermal operation, both configurations result in an exact yield as carrier conversion stays below 33.33%. The char residence time, which determines the rate-limiting step, remains the same in both configurations, enabling seamless transition between the two configurations.

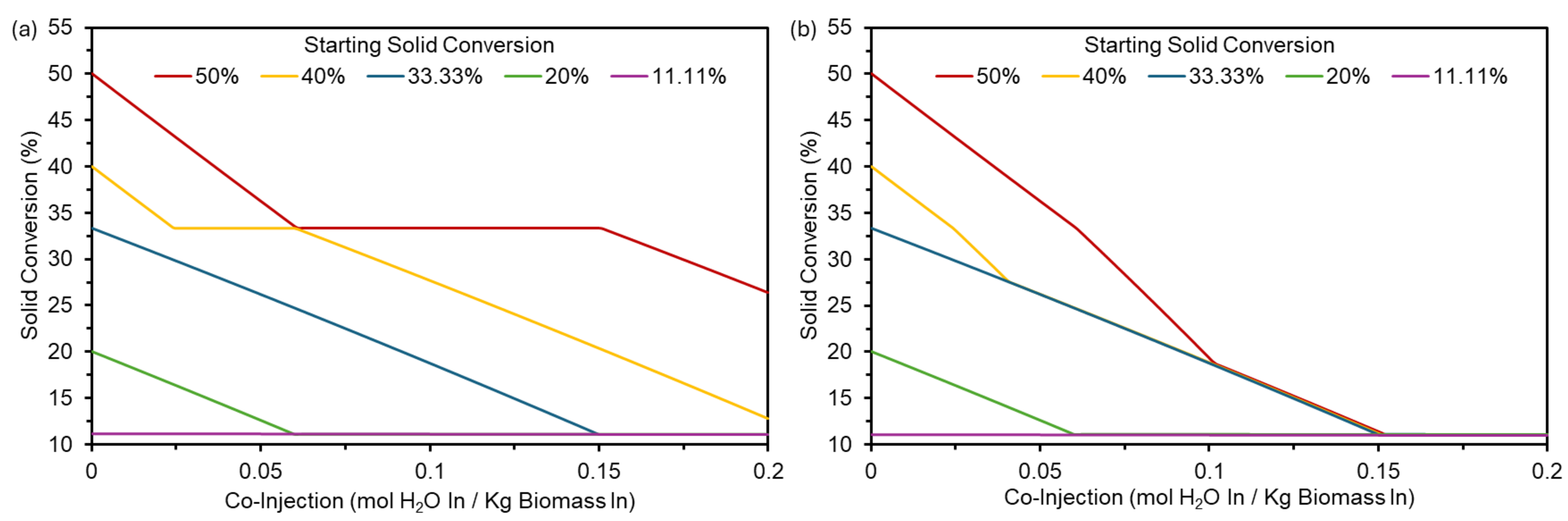

Figure 3: Solid Conversion for (a) Co-Current and (b)Cross-Current Reactor Configuration[3]

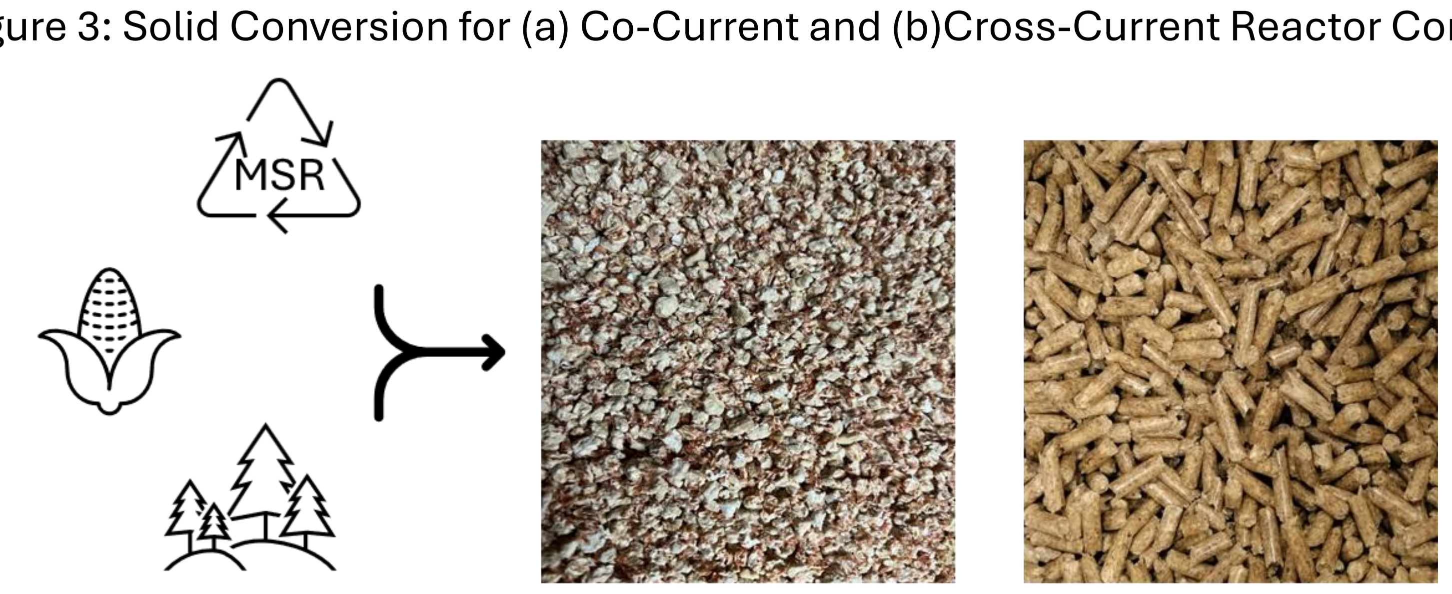

Figure 4: Various Biomass Sources

4 – Benefit to Society

This chemical looping technology has been developed specifically to valorize non-feedstock biomass sources such as corn cob, hardwood pellets, etc., as presented in Figure 4.[4] The syngas that will be generated can be upgraded downstream to produce chemicals such as aviation fuel, methanol, etc. **Furthermore, as biomass is almost carbon neutral and CO2 can be used as a feedstock for the process, the overall technology has the potential to be carbon negative.**[3] Thus, this technology, along with the development effort presented, has the potential to positively impact climate change while simultaneously producing a key chemical intermediate.

5 – Next steps

The co-current system has been tested at a sub-pilot scale[4], while the advantage of the cross-current system is only verified through process simulations. The immediate next step is to experimentally validate the findings at the same scale while simultaneously conducting economic evaluations, thereby de-risking scale-up.

References & Acknowledgements:

[1] A. Joshi et al., Advances in Applied Energy. 3, 100044 (2021).
[2] https://oied.osu.edu/fans-chemical-looping-technology-licensed-ohio-based-babcock-wilcox
[3] A. Joshi et al., Energy Fuels. 37, 16744–16756 (2023).
[4] C. Park et al., Fuel Processing Technology. 252, 107966 (2023).

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