Techno-economic evaluation of Chemical-Looping Gasification (CLG) for liquid fuel production from biomass and with net negative emissions of CO_2

We are looking for Master thesis students to conduct a thesis project within the field of energy technology. The project is suitable for 1-2 students with background in mechanical or chemical engineering with an interest in energy systems, process modelling and thermodynamics.

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Background

There is a need for drastic reductions in emissions of carbon dioxide from combustion of fossil fuels. The transportation sector is a major source of greenhouse gas emissions, and it is necessary to reduce these significantly to meet climate targets. One such method is to replace liquid fossil fuels, with fuels derived from biomass or biomass waste. The purpose of the work is to study a novel gasification process, which can enable efficient production of syngas from biomass, a gas which can then be converted to liquid fuels.

Chemical-looping combustion (CLC) of solid fuels is a potential break-through technology with respect to costs and energy penalty for CO_2 capture, see Fig. 1. CO_2 capture and storage (CCS) has been recognized internationally as one of the most important options for climate mitigation. Previously CCS technologies have had a focus on fossil fuels, but perhaps even more important may be to use CCS with bioenergy, so called BECCS, in order to remove CO_2 from the atmosphere. Such "negative emissions" will likely be necessary to meet recently decided climate targets. Chemical-looping gasification (CLG) is similar to CLC, but with the important difference that the idea is to produce syngas, a gas consisting mostly of CO and H_2. This is an important precursor for chemical and fuel production, such as methanol or dimethyl ether, DME.

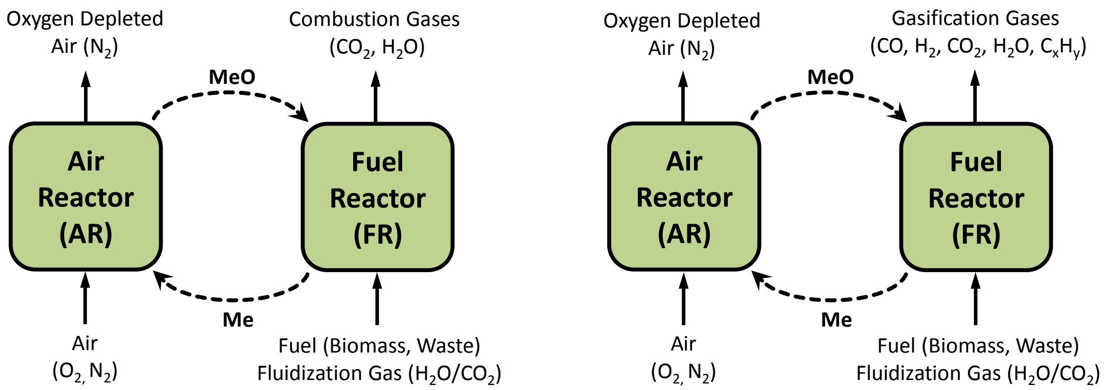

Figure 1: a) Chemical-looping combustion (left) and b) Chemical-looping gasification (right).

In comparison to other emerging technologies for CO_2 capture, CLC and CLG are unique in avoiding large costs and energy penalties associated with gas separation. This is possible because oxygen is transferred from air to fuel using metal oxides, and thus fuel and air are never mixed and consequently the capture of CO_2 is inherent in the combustion process for CLC, and in CLG the carbon is highly concentrated, opening up for efficient separation of carbon while at the same time producing valuable products. In the current project, partly financed by the Swedish Energy Agency, we are looking to developing this exciting technology, and includes pilot operation, oxygen carrier development and techno-economic analysis. The proposed thesis work is related to the latter, where it is proposed that a student conduct a so called "Well-to-Wheel" analysis of the entire process chain.

Aim & method

The project is aimed at developing the CLG technology and evaluate the viability of such an endeavor with respect to process efficiency, costs and greenhouse gas emissions. You will be working in a research group with different tasks related to the gasification process, and your role will be to perform the overall techno-economic evaluation using the knowledge gained from experiments and prior work. The tasks could include:

- Thermal evaluation of the core gasification process, with aim of determining optimal process parameters for gasification.
- Definitions of boundary conditions, i.e. type of biomass fuel, final product and site conditions.
- Analysis of an integrated process with efficient heat integration of process components.
- Evaluation of relevant costs, related to fuel, transportation and down-stream synthesis processes, such as Fischer-Tropsch.
- Calculation of important parameters, such as cost of product fuel, efficiencies of the total "well-to-wheel" process and CO_2 emissions.
- Evaluation of important constraints and possible future key areas of research.

Work structure

The list below describes possible parts of the work to be carried out. The work structure can obviously be kept rather flexible as long as the focus of the project is maintained.

1. Establishing a time plan of the work with advisors.
2. Initial review of relevant literature around CLC, CLG and system studies thereof.
3. Definition of boundary conditions for the value chain.
4. Thermal and thermodynamic evaluation of gasification process. Here standard tools can be employed or employment of software such as Aspen, HSC or Ebsilon.
5. Development of an integrated model, with efficient heat integration. Process simulation tools such as Aspen and pinch analysis could be employed.
6. Cost analysis of important parts in the value chain, from fuel cost, transportation, gasification process and fuel production should be analysed.
7. Determination of important parameters, such as final product cost, efficiency and greenhouse gas emissions.
8. Reporting