Biomass residues to synthetic gases and renewable natural gas in a pilot two-stage fluidized bed gasifier and fixed bed methanator

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There are estimated 30 million tonnes of forest residues available each year at British Columbia, which can be converted to high-value biofuels or biochemicals. Pulp & Paper mills are the largest industrial user group of natural gas in the province of BC and lime kilns are the major use of fossil fuel on a pulp mill site. Currently, both Federal and Provincial governments are looking to reduce GHG emissions, and syngas and renewable natural gas (RNG) from forest residues are identified to be cost-effective products to help reach the above goals. Displacing natural gas use in pulp and paper mills in British Columbia will effectively help the government reach its GHG reduction targets. While displacing natural gas use in pulp and paper mills is a promising option, a full-scale plant that makes Renewable Natural Gas (RNG) sized to the available hog fuel supply in the region, rather than the fuel demand for a lime kiln, can generate a substantially larger GHG impact.

This project aims to support the forest and pulp and paper industry to produce renewable syngas and natural gas as a key part of bioeconomy for Canada. The RNG team of the BC Bioproducts Alliance, composed of UBC, FPInnovations and Pulp & Paper mills in BC, has been working fruitfully on identification and development of gasification technology, on sharing of pulp and paper knowledge and experience, and on training of highly qualified personnel for further developing value-added bioeconomy utilizing forest residues.

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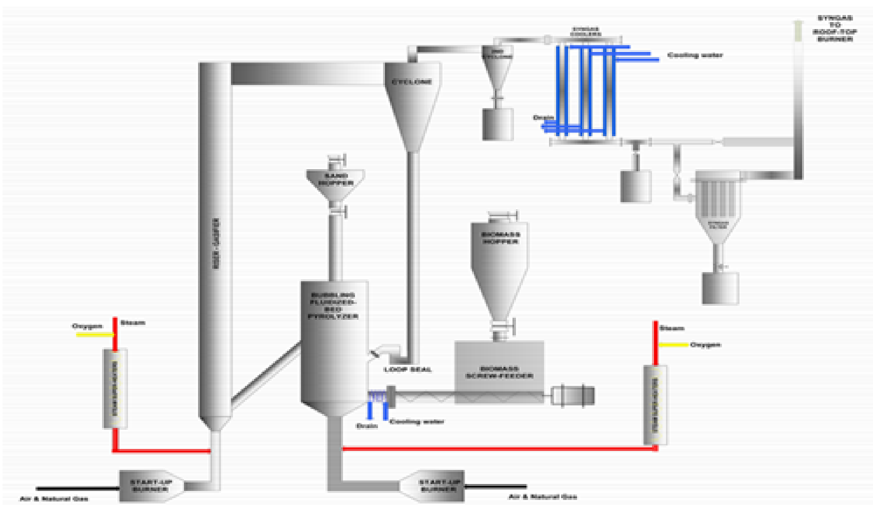
The objectives of the work are to 1) design and commission a pilot scale two-stage fluidized bed biomass gasification system at UBC; 2) build a mobile syngas cleanup and methanation system and test with synthetic syngas and syngas from the pilot gasifier; 3) enhance interactions with selected Alliance mills for process integration studies where a biomass gasifer is proposed to be installed to generate syngas for lime kiln.



In the gasification process, biomass is partially oxidized into syngas ($CO + H_2$), together with small quantity of higher hydrocarbons called tar. The quality of the syngas impacts the subsequent operations of the cleaning and methanation of syngas. Two key indicators, which determine the quality of syngas, are the tar concentration and the percentage of inert gas (e.g. N_2 and CO_2) in the syngas. Clearly, low syngas tar content and inert gas concentration are favoured for the subsequent syngas cleaning and methanation.

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Using pure oxygen or a mixture of oxygen and steam to replace air as the gasification agent is a promising method to substantially reduce the concentration of inert gas in the syngas. The review of different gasification technologies indicates that two-stage gasification technology has a promising performance in generating syngas of lower tar content. The air-blown two-stage gasification process has been demonstrated at a commercial scale by the Institute of Process Engineering (IPE), Chinese Academy of Sciences, which showed the tar content in syngas could be as low as ~50 mg/Nm3. However, its performance is still unknown with oxygen or oxygen/steam as the gasification agent. In this project, we have designed and commissioned a pilot steam/oxygen two-stage fluidized bed gasifier with a processing capacity of 20 kg/hr dry biomass to evaluate the performance using different biomass feedstock and steam/oxygen ratio. As a first step of development and commercialization of RNG production technologies, it is proposed here to fire lime kilns with low-tar syngas generated on-site to substitute purchased natural gas.

One essential step in converting gasification syngas to methane is the cleanup of the synthetic gas generated from the gasifier before the syngas can be further fed to the methanation reactor. Tars, largely aromatic, high-molecular-weight hydrocarbons including complex polycyclic aromatic hydrocarbons, are highly problematic because of their condensation and polymerization tendencies. Bauxite residue is a by-product of bauxite processing through the Bayer process, mainly consisting of a mixture of oxides of Fe, Al, and Ti. Our preliminary investigation using bauxite residue as tar-cracking catalyst in a bench-scale unit has demonstrated that naphthalene conversion of bauxite residue catalyst is comparable to a commercially available Ni-based catalyst for temperatures of 800 and 850oC at space velocities of 4,500 and 19,000 h-1, which is significant and gives us the confidence to pursue further investigation in a prototype unit using real syngas from biomass gasifiers.

Cleaned syngas is converted to methane in a catalytic reactor. Although commercially available methanation catalysts have been widely used for converting coal-derived syngas, there is limited understanding of the catalyst performance when using biomass-derived syngas, especially with respect to potential catalyst deactivation from trace contaminants. In this proposed work, we will carry out systematic experiments in a prototype fixed bed reactor unit to identify, develop and experimentally verify the most-suitable commercial catalysts and operating conditions for the biomass-derived syngas methanation process (e.g. tolerance to S, N, Cl, metals, tar, coke, PM, etc.).

The projects activities will advance new clean technologies for biomass conversion to syngas and demonstrate at pilot scale that these are suitable for combustion in a lime kiln and for further conversion to RNG. Subsequently, with the outcomes of the Test/Pilot phase, a demonstration plant will be designed and constructed to be located at a BC pulp mill. The demonstration plant and future rollout of commercial plants will lead to significantly reduced CO2 emissions when compared to current fossil fuels used to power lime kilns, and therefore substantially reduce the GHG footprint of BC pulp and paper mills.

A pilot two-stage fluidized bed gasifier has been developed and commissioned with a biomass feed rate of 20 kg/hr. A slip stream of syngas will be taken from the gasifier for the test of catalytic tar cracking and syngas methanation to RNG in fixed bed reactors.

In parallel, researches are carried out on biomass supply logistics for selected BC pulp and paper mills (Taraneh Sowlati, shahab Sokhansanj, Anthony Lau) and the evaluation of combustion characteristics of biomass-derived syngas in lime kilns (Patrick Kirchen), supported by a NRCan Clean Growth project.