IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Techno-economic evaluations of coal and biomass pyrolysis with carbon capture for syngas feedstock to ammonia production
Project Number	**IMURA0221**

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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1. Advanced computational engineering, simulation and manufacture
2. **Infrastructure Engineering**
3. **Clean Energy**
4. Water
5. Nanotechnology
6. **Biotechnology and Stem Cell Research**

The research problem

Producers of industrial chemicals such as ammonia increasingly have a responsibility to investigate methods where the products have less impact on the environment. Ammonia is produced from hydrogen and nitrogen. Syngas provides the source of hydrogen gas for reaction with nitrogen gas to form anhydrous ammonia. Syngas is a mixture of hydrogen, carbon monoxide and carbon dioxide that is commonly produced by reforming natural gas in the presence of steam over a metal alloy catalyst, which is usually nickel based. This process is known as steam reforming of natural gas. The natural gas is mixed with combustion air and burned to produce heat inside a reformer unit, before waste heat is removed from the flue gas which is vented to atmosphere. The flue gas emits carbon dioxide, and along with the carbon dioxide that is removed from the process gas stream post hydrogen production, these emissions constitute the major greenhouse gas emissions from an online ammonia manufacturing plant. The natural gas used in ammonia manufacture constitutes the vast majority of operating costs so any method that reduces the dependence on this hydrocarbon could also have a significant impact of plant economics

Renewable fuels and feedstocks may offer the opportunity to reduce costs and the overall carbon dioxide emissions. This project will look at processes based a renewable form of hydrogen, which can be produced from organic materials under certain processing conditions. When biomass is heated in an oxygen-limited environment a process known as pyrolysis occurs, yielding a mixture of bio-char and bio-fuel. The solid product is a form of charcoal and the bio-fuel can be bio-oil and/or syngas.

Various technologies for biomass pyrolysis exist or are under development, although capture of any emitted CO2 is not yet included in these processes.

Relevant Background and additional information:

The project is expected to involve a mix of heat and mass balance-based process flow modelling, supplemented by experimental analysis (using TGA, and fluid bed reactors) of biomass pyrolysis to generate understanding of likely gas and pollution composition ranges, as compared to that of coal pyrolysis. Appropriate gas-separation experiments may also be conducted.

Relevant literature:

Ulgiati, S., Raugei, M., and Bargigli, S., (2006), Overcoming the inadequacy of single-criterion approaches to Life Cycle Assessment, *Eco. Mod*., **190**, 3-4, 432-442.

Dominguez-Ramos, A., Aldaco, R., and Irabien, A., (2007), Life Cycle Assessment as a Tool for Cleaner Production: Application to Aluminium Trifluoride, *Int. J. Chem Reaction Engng.,* **5**, A33.

Project aims

To identify and assess leading technologies for coal and biomass pyrolysis in the generation of ammonia from syngas feedstock, with the inclusion of CO2 capture. The project would involve techno-economic evaluations of the identified processes, and the best current and projected costs and overall energy and CO2 penalties would be identified, enabling the identification of the most fruitful avenues to pursue.

Expected outcomes

Highlight the expected outcomes of the project

The project outcomes are expected to include:

comparison of the economic and environmental credentials of existing routes for ammonia production with those of alternate flowsheets involving hydrogen production via integrated coal and/or biomass pyrolysis.

Experimental results for the pyrolysis gas compositions of different biomass and coal feed sources

Heat and mass balance process flow models, LCA and other environmental performance metrics, coupled with economic scenario analysis (defining biomass type) to form the basis of the process comparisons.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Essential: Undergraduate or Masters Degree in Chemical Engineering, with a background in Chemistry

Desirable: Knowledge and experience in process flow simulation

Desirable: Environmental Chemistry or Engineering experience

Desirable: Understanding of pyrolysis and fluidised bed technology

Desirable: Knowledge and experience in Life Cycle Ana