AIE POSTGRADUATE STUDENT ENERGY AWARDS 2012

In conjunction with

All-Energy Australia Exhibition & Conference
Melbourne Conference & Exhibition Centre
10th & 11th October 2012

Generously Sponsored by:

- *Dept of Primary Industries* and
- *Clean Coal Victoria*

And supported by:

THE AUSTRALIAN INSTITUTE *of* ENERGY

MELBOURNE BRANCH

Introduction

10th October 2012

The Australian Institute of Energy - Melbourne Branch is pleased to stage another of its biennial Postgraduate Student Energy Awards events, again with the strong support of the All-Energy Australia Exhibition and Conference. Our last such event was held in October 2010 when 22 student poster submissions were received and displayed. This year we welcome you to view 30 posters. We believe that you will be excited by what you see and hear and are confident that you will enjoy this successful event. On behalf of the AIE Melbourne Branch and our sponsors, we thank you for your interest.

The purpose of this event is to provide students with the opportunity to present their postgraduate energy research projects to a public comprised of energy professionals and other interested persons. The students' objective is to communicate their particular topic via a poster, a summary (found in this booklet) and personal discussions. They will be seeking to convey not only the nature of their project but also its relevance and importance in the energy space. Some of the work displayed is at the early stages of development whereas other work has been researched for some time and, in some cases, is close to submission as a thesis.

We invite you to circulate around the poster displays and discuss the projects with the students. Your attentive listening, helpful hints, constructive advice and assistance based on your experience will be welcomed by the students. We are confident that the experience will be rewarding to you and the students, as you learn more about leading-edge energy research currently being undertaken at our universities. Your participation can potentially contribute to the on-going debate on Australia's future energy direction.

The Awards event is underpinned by the generosity of our sponsors; their financial support has made this special event possible. We express our sincere thanks to each of our sponsors listed below. Please consult their websites for more information about their products, services and activities. They will appreciate your support.

Major Sponsors: **Department of Primary Industries -** *www.dpi.vic.gov.au/energy*

Brown Coal Innovation Australia - *www.bcinnovation.com.au*

Other Sponsors: **Clean Energy Council -** *www.cleanenergycouncil.org.au/*

Clean Coal Victoria - *www.dpi.vic.gov.au/earth-resources/coal/prospectivity/clean-coal-victoria*

Of the 30 posters, there are 17 entries from Monash University, 10 from the University of Melbourne, 2 from RMIT University, and 1 from Victoria University. To all the students who have put in a substantial effort, including many hours and creativity on their posters, the Branch and the sponsors heartily express their thanks. We congratulation the students for the high standard of their displays, summaries and explanations. We are sure that their achievements at this Awards event will be a significant step in your chosen thesis topic and future career path.

In addition to the Awards, the AIE is delighted to invite all of the participating students who are not already members to join the AIE with no charge for this year.

Please explore and discuss the posters with the students! Thank you for your support.

David Allardice

David Allardice
AIE Event Convenor

LIST OF STUDENT PROJECTS AND DISPLAYS

DISPLAY NO	STUDENT	TERTIARY INSTITUTE	DEPARTMENT	COURSE	STAGE	PROJECT TITLE	ENERGY FIELD	SUPERVISOR
1	Amir Valizzadeh **KIVI**	Melbourne	Infrastructure Eng	PhD	2nd yr	Adapting Geothermal Energy for Victorian conditions	Geothermal	Prof I Johnston Dr G Narsilio
2	Joanne **MOORE**	Monash	Chem Eng	PhD	1st yr	Brown coal derived Syngas generation for utilisation in higher value product processes	Brown Coal	A/Prof S Bhattacharya
3	Bartlomiej **KOLODZIEJCZYK**	Monash	Materials Eng	PhD	1st yr	Conducting polymer alloys for photo-enhanced electro-catalytic oxygen reduction.	Fuel Cells	A/Prof B Winther-Jensen
4	Fiona **LOW** Chai Foong	Monash	Chem Eng	PhD	2nd yr	Clarifying the emission and control of toxic trace metals during coal oxy-fuel combustion	Brown Coal	Dr L Zhang
5	Mowffaq **OREIJAH**	RMIT	Aerospace, Mech & Manuf Eng	PhD	3rd yr	Power generation from hydrothermal resources using simple reaction turbine	Renewable Energy	Prof A Akbarzadeh
6	Hendy **THEE**	Melbourne	Chem & Biomol Eng	PhD	3rd yr	Making Carbon Capture cheap and environmentally friendly	CCS	Prof G Stevens
7	Simon **TAKOURIDIS**	Melbourne	Chem & Biomol Eng	PhD	2nd yr	The domestication of Algae for Green Energy	Renewable Energy	Greg Martin
8	Adam **RADY**	Monash	Chem Eng	PhD	2nd yr	Victorian brown coal as a fuel for Direct Carbon Fuel Cells	Brown Coal	A/Prof S Bhattacharya
9	Chun Hin **NG**	Monash	Materials Eng	PhD	1st yr	Light assisted water electrolysis on dye/conducting polymer blends	Hydrogen	A/Prof B Winther-Jensen
10	Andri **HALIM**	Melbourne	Chem & Biomol Eng	PhD	3rd yr	Nano-flowers to capture CO_2	CCS	Prof Greg Qiao
11	Andre **STEPHAN**	Melbourne	Architecture	PhD	2nd yr	Towards a more holistic energy assessment of residential buildings	Building Energy	R Crawford
12	Bithi **ROY**	Monash	Chem Eng	PhD	2nd yr	Combustion behaviour of Victorian Brown coal in fluidized bed under oxyfuel combustion	Brown Coal	A/Prof S Bhattacharya
13	Fengling **ZHOU**	Monash	Chemistry	PhD	2nd yr	Investigation of inorganic metal oxide catalysts for photochemical water splitting	Hydrogen	Prof L Spicia Prof D MacFarlane
14	Richelle **LYNDON**	Monash	Chem Eng	PhD	2nd yr	Photo-switchable metal organic frameworks for carbon capture	CCS	A/Prof B Ladewig Dr M Hill
15	Kannan Jegathala **KRISHNAN**	Victoria	Engineering & Science	PhD	3rd yr	Implementation of Renewable Energy to reduce carbon tax and fuel cell as back-up for NBN	Renewable Energy	Prof A Kalam

To find a poster, they are arranged in numerical sequence, anti-clockwise from the AIE booth L210.

LIST OF STUDENT PROJECTS AND DISPLAYS (Cont.)

DISPLAY NO	STUDENT	TERTIARY INSTITUTE	DEPARTMENT	COURSE	STAGE	PROJECT TITLE	ENERGY FIELD	SUPERVISOR
16	Sunaina **DAYAL**	Monash	Chem Eng	M Eng Sc	1st Yr	Entrained flow gasification of brown coal - comparison of slag viscosity models	Brown Coal	A/Prof S Bhattacharya
17	Tshewang **LHENDUP**	Melbourne	Engineering	PhD	3rd Yr	Inter-seasonal thermal storage	Renewable Energy	A/Prof L Aye
18	Ali Habibi **KHALAJ**	Melbourne	Mech Eng	PhD	1st yr	Energy efficiency enhancement of Data Centres using cold aisle containment	Building Energy	Prof Saman Halgamuge
19	Kawnish **KIRTANIA**	Monash	Chem Eng	PhD	2nd yr	Biomass conversion in entrained flow reactor for cleaner power generation	Renewable Energy	A/Prof S Bhattacharya
20	Bayzid Kabir **KAZI**	Monash	Chem Eng	PhD	2nd yr	Assessment of Dimethyl ether synthesis from Victorian brown coal	Brown Coal	A/Prof S Bhattacharya
21	Saliya **JAYASEKARA**	Melbourne	Mech Eng	PhD	3rd yr	Trigen: A holistic approach to optimise heating, cooling & electricity for bulk energy consumers	Energy systems	Prof Saman Halgamuge
22	Alireza **MOHAMMADI**	Melbourne	Mech Eng	PhD	3rd yr	Online optimisation of spark advance in alternative fuelled engines	Alternative Fuels	A/Prof Chris Manzie
23	Robert **KERR**	Monash	Materials Eng	PhD	3rd yr	A Rotating Ring-Disc study into the Oxygen reduction reaction on Pedot Electrodes for fuel cells & batteries	Fuel Cells	A/Prof B Winther-Jensen
24	David **STOKIE**	Monash	Chem Eng	PhD	2nd yr	Experiments in Steam fluidised bed drying of low rank coals	Brown Coal	A/Prof S Bhattacharya
25	Baljit **SINGH**	RMIT	Aerospace, Mech & Manuf Eng	PhD	2nd yr	Power generation from solar pond using thermoelectric generators.	Renewable Energy	Prof A Akbarzadeh
26	Jean Christoffe **LI** Yuen Fong	Monash	Chem Eng	PhD	2nd yr	Exergy analysis of CO_2 compression vs liquefaction	CCS	A/Prof A Hoadley
27	Braden **KIDD**	Melbourne	Engineering	M Eng Sys	1st yr	DC hybrid remote area power system	Energy systems	A/Prof M Brear
28	Sharmen **RAJENDRAN**	Monash	Chem Eng	PhD	1st yr	Experimental Investigation of chemical looping combustion of Victorian brown coals using Hematite	Brown Coal	A/Prof S Bhattacharya
29	Sonal **THENGANE**	Monash	Chem Eng	PhD	2nd yr	Techno-economic evaluation of water splitting technologies to produce H_2 for NH_3 production	Renewable Economics	A/Prof A Hoadley
30	Wirhan **PRATIONO**	Monash	Chem Eng	PhD	1st yr	Advancing the Oxy-fuel combustion of Victorian brown coal for low carbon emission	Brown Coal	Dr L Zhang

To find a poster, they are arranged in numerical sequence, anti-clockwise from the AIE booth L210.

The Awards and Categories

The objective of this event is to give the 30 students listed on the previous pages the opportunity to explain their postgraduate energy research projects to the energy professionals attending. Each student will communicate his or her project and its relevance to energy through a **poster display**, **a printed summary sheet** (bound in this booklet) and **personal explanations** of their project. The students should be aiming to get their message across to 'an informed layman', who does not have expertise in the student's field.

The projects and their Display Numbers are listed in the table on previous page. The student projects have been divided into two groups with equal numbers of projects and some common elements within a group, to give the students an equitable chance of winning an award. The broad groupings are:

- **'Renewable Energy and Energy Systems'** - The odd numbered projects in the previous table
- **'Fossil Fuels'** (including Carbon Capture and Storage) - The even number projects in the shaded rows in the previous table.

These groupings may look awkward but we have to work with the projects that have been entered.

Five awards will be presented following an assessment of the projects by a panel of 'judges'. The assessment is based on each of the elements above. The winners will be announced and awarded their prizes at the end of the opening session of the Young Energy Professionals Conference Stream in the All-Energy Conference on Thursday 11th October.

The Awards and their sponsors are listed below. The three best projects will represent Victoria at the AIE National Postgraduate Student Energy Awards associated with the AIE National Conference in Sydney on 19th and 20th November 2012, including a travel allowance and complementary registration at the conference.

Award	Sponsor
RENEWABLE ENERGY AND ENERGY SYSTEMS (Odd numbered projects)	
Best Project - $750 and nomination for the National Postgraduate Student Energy Awards	**Dept of Primary Industries, Victoria**
Runner Up - $500	**Clean Energy Council**
FOSSIL FUELS (Even numbered projects in shaded rows)	
Best Project - $750 and nomination for the National Postgraduate Student Energy Awards	**Brown Coal Innovation Australia**
Runner-Up - $500	**Clean Coal Victoria**
Encouragement Award - effectively 3rd place (All projects)	
$500 and nomination for the National Postgraduate Student Energy Awards	**All-Energy Australia & AIE**

The project summary sheets are reproduced in sequence following this page. The project posters will be on display in 2 areas of the Exhibition Hall, (the farthest corners from the entrance).

To find a poster, they are arranged in numerical sequence, anti-clockwise from the AIE booth L210.

ADAPTING GEOTHERMAL ENERGY FOR VICTORIAN CONDITIONS

Student: Amir Valizadeh Kivi **Display No.: 01**

Email Address: amirvk@pgrad.unimelb.edu.au

Enrolled for: PhD **Status**: 2nd year

Tertiary Institution: University of Melbourne **Department**: Infrastructure

Supervisors: Prof. Ian Johnston, Dr. Guillermo Narsilio

Phone: +61 3 9035 8034 **E mail**: ianwj@unimelb.edu.au, narsilio@unimelb.edu.au

Project Summary:

Direct geothermal energy systems use the earth as a heat source or sink to heat and cool buildings. They use considerably less electricity than conventional systems. By reducing electricity demand, these systems have the potential to significantly reduce Australia's electricity use and carbon footprint. Direct geothermal systems have been commercialised in countries with long cold seasons over the last couple of decades. Among the many design parameters, there are several parameters that can be quite different for Victorian (and Australian) conditions as compared to countries in which design guidelines have been developed. These include the *annual mean temperature*, *temperature swing, temperature fluctuation* and *ground thermal properties*. These local parameters appear to be conducive to much improved efficiencies in the use of these systems than in the cooler climates. Consequently, the use of these existing geothermal guidelines is likely to lead to over-conservative designs if directly applied in Victoria. Based on a critical review of these methods, this research aims to improve current design techniques by performing field experiments using instrumented pilot geothermal systems, and incorporating local heating/cooling load and geological characteristics. For this research, a horizontal full scale geothermal system with more than 200 temperature sensors has been installed at Main Ridge (Mornington Peninsula) and a vertical full scale system with more than 100 sensors at the Walter Boas Building at the University of Melbourne.

The research objectives are:

- Monitor the performance of the full scale geothermal systems,
- Analyze the results to assess the observed heat gain/rejection from/to the ground under Victorian (Australian) conditions,
- Improve and/or develop new design techniques,
- Demonstrate the potential for direct geothermal systems,
- Increase public awareness of direct geothermal systems in Australia.


Main Ridge Horizontal Geothermal


Walter Boas Vertical Geothermal

BROWN COAL DERIVED SYNGAS GENERATION FOR UTILISATION IN HIGHER VALUE PRODUCT PROCESSES

Student: Joanne Moore **Display No.: 02**

Email Address: joanne.moore@monash.edu

Enrolled for: PhD **Status:** 1st year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: A/Professor Sankar Bhattacharya / Professor Klaus Hein

Phone: +61 3 9905 9623 **Email:** sankar.bhattacharya@monash.edu / klaus.r.g.hein@t-online.de

Project Summary:

The majority of worldwide population growth in the foreseeable future will be in developing countries and will be accompanied by a corresponding increase in demand for food, mobility and standards of living. With this increase in demand, there will almost certainly be a worldwide reduction in the availability of oil and gas at increased costs. One potential solution to this projected shortage may be the use of coal derived gases and liquids as alternative fuels and industrial feedstocks. The use of brown coals for this purpose is of particular interest due to their low cost, long term availability and advantageous physical and chemical properties.

The vast reserves of brown coal In Victoria are utilised almost exclusively in mine-mouth power generation facilities based on obsolete combustion technology. Thus an opportunity exists to investigate the conversion of this abundant, low quality resource into high quality, value added products for domestic and international markets.

The current commercial gasification technologies are ubiquitously based on entrained flow technologies that can achieve higher carbon conversion and a cleaner syngas product than the previously more prolific moving and fluidised bed technologies. While data for various gasification processes is available for European brown coals and US lignites, the direct extrapolation of this data to predict the gasification behaviour of Victorian brown coals is not practicable due to their unique properties and the diverse range of operating conditions employed in previous studies.

This project aims to significantly increase in the knowledge of syngas generation by the entrained flow gasification of Victorian brown coal using the following broad research methodology:

- Detailed bench and semi-technical scale pyrolysis and gasification trials under a matrix of test conditions representative of existing industrial processes to enable extensive gas and solids sampling and analysis
- Application of the results of these trials to evaluate case-related kinetic data
- Utilisation of this data to develop and validate mathematical models of syngas generation modes for various product processes of interest
- Interpretation of the collective final results in relation to the use of Victorian brown coal-derived syngas as an input to higher value product processes

The project will concentrate on the previously unexplored area of entrained flow gasification of Victorian brown coal where kinetic data is virtually unavailable, and therefore of particular interest. The overall objective will to develop a comprehensive model, validated with experimental data, of the process of gasification of Victorian brown coal under various conditions to be utilised for process design and modelling of large scale application.

CONDUCTING POLYMER ALLOYS FOR PHOTO-ENHANCED ELECTRO-CATALYTIC OXYGEN REDUCTION

Student: **Bartlomiej Kolodziejczyk** **Display No.: 03**

Email Address: bartlomiej.kolodziejczyk@monash.edu

Enrolled for: PhD **Status:** 1st year

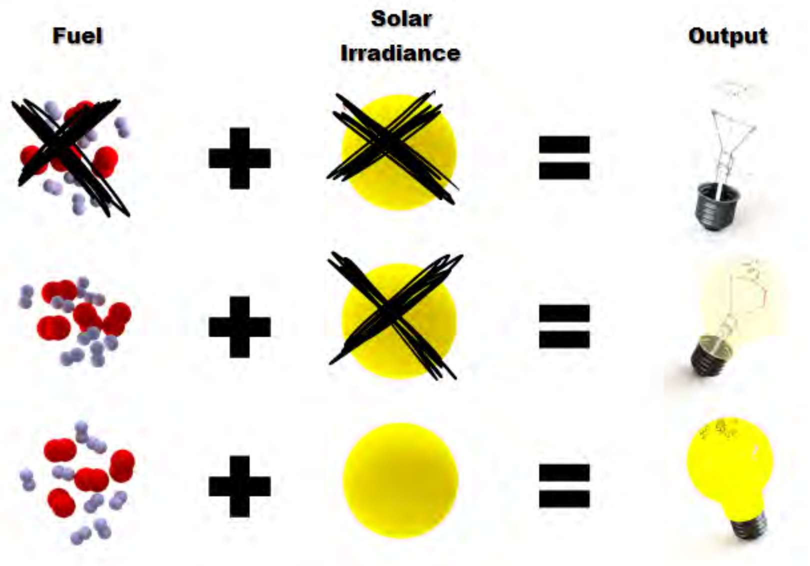
Tertiary Institution: Monash University **Department:** Materials Engineering

Supervisor: A/Prof Bjorn Winther-Jensen, Prof Douglas MacFarlane

Phone: +61 3 9905 5343 **E mail:** bjorn.winther-jensen@monash.edu

Project Summary:

Fuel cells convert chemical energy directly into electrical energy and heat with high efficiency and low emission of pollutants. However, before fuel cell technology can gain a significant share of the energy market, many important issues have to be solved. These issues include many different aspects, one of them is the development of alternative materials for fuel cells. Present fuel cell prototypes very often use materials selected when fuel cells gained interest, it was more than 30 years ago. Commercialization aspects, including cost and durability, have revealed inadequacies in some of these materials. Most of fuel cell catalysts are based on platinum, a noble metal with good catalytic properties, however platinum makes catalyst one of the most expensive components of fuel cell. Other issue using platinum is platinum poisoning, platinum catalytic properties are decreasing rapidly when metal is exposed to carbon monoxide.



We present novel electro-catalyst based on polymeric alloy. Poly(3,4-ethylenedioxythiophene) or PEDOT is a conductive polymer with great electro-catalytic properties (comparable to platinum) when used for oxygen reduction. Polythiophene is also conductive polymer, widely used in solar cells, while poly(ethylene glycol) or PEG is very common material used in range of application. When all three polymers are mixed together in interpenetrating network, they create hetero-junction material. PEDOT act as electro-catalyst, which properties can be light enhanced with help of polythiophene, when light is shining on its surface. PEG improves ionic and electrical conductivity of the alloy. Over-potential need to reduce oxygen can be decreased by around 600 mV when light is shining on the alloy's surface. This novel material is easy and cheap to manufacture, and can open new field of energy converting devices, where fuel cell and solar cell are combined in one scheme. First tests show very promising results, which can be further improved by optimizing alloy's composition and using proper fuel cell setup.

CLARIFYING THE EMISSION AND CONTROL OF TOXIC TRACE METALS DURING COAL OXY-FUEL COMBUSTION

Student: Fiona Low Chai Foong **Display No.: 04**

Email Address: fiona.low@monash.edu

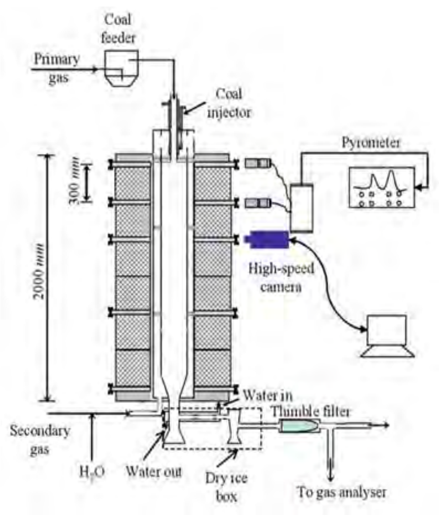
Enrolled for: PhD **Status:** 2nd year

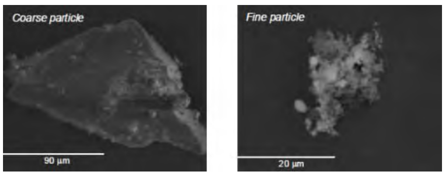
Tertiary Institution: Monash University **Department**: Chemical Eng

Supervisor: Dr. Lian Zhang

Phone: +61 3 9905 2592 **Email Address:** lian.zhang@monash.edu

Project Summary :

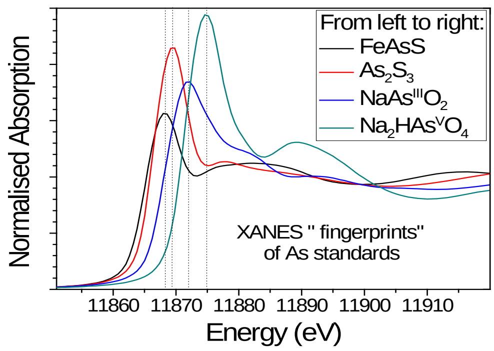




Coal is a major source of energy, contributing to ~40% of the total electricity produced globally. However, coal combustion has huge environmental implications as apart from CO_2 emissions, the vast total amounts of coal combusted release undesirable quantities of hazardous elements. In addition to their concentrations, knowledge on their modes of occurrence in coal/ash is equally important as it strongly influences their rate of release into the environment and subsequent health risks associated with coal utilisation. For instance, the As^{3+} form of arsenic is fifty times more toxic than the As^{5+} form.

Oxy-fuel combustion, a process which uses high purity oxygen mixed with recirculated flue gas for coal combustion to deliver a CO_2-rich flue gas for direct sequestration, is a low risk, promising technology for CO_2 abatement. However, the gas environment in the furnace will be greatly altered, thus increasing uncertainty regarding the emission of toxic trace metals, and for this case, will also negatively affect CO_2 quality, a key factor affecting subsequent CO2 compression and sequestration. To date, literature studies on trace element emission and speciation are limited to that derived under conventional air firing conditions. Moreover, little is known about the trace metals in Victorian brown coal (VBC), which is the single largest source for power generation in Victoria.

To study these, coal of various types were combusted in a laboratory-scale drop-tube furnace (DTF, top left picture) using a variety of gas conditions designed to simulate that of oxy-fuel combustion. The un-emitted trace metals remaining in the char and ash (picture below DTF) were collected and analysed by advanced facilities including inductively-coupled plasma optical emission spectrometry (ICP-OES), X-ray fluorescence (XRF) spectrometry and synchrotron-based X-ray absorption spectroscopy (XAS, right picture) to clarify the content and mode of occurrences of individual metals.



Significant findings relating to this project that were successfully published include optimisation of microwave digestion conditions, a sample preparation precursor for element quantification by ICP-OES; and also a research on the emission, speciation and capture of arsenic under oxy-fuel conditions for three different coals including the VBC.

POWER GENERATION FROM HYDROTHERMAL RESOURCES USING A SIMPLE REACTION TURBINE

Student: Mowffaq Oreijah **Display No.: 05**

Email Address: s3264542@student.rmit.edu.au

Enrolled for: PhD **Status:** 3rd year

Tertiary Institution: RMIT university **Department:** Mechanical Engineering

Supervisor: Prof. Aliakbar Akbarzadeh

Phone: +61 3 9925 6079 **Email:** akbar@rmit.edu.au

Project Summary:

This research aims to design and to develop the reaction turbine in order to generate power from the geothermal resource as renewable and clean energy. The project scope includes developing the reaction turbine, figure1, as a part of the system that will be designed and developed with the binary system. The system includes reaction turbine, heat exchanger, condenser and feed pump. The system can be operated with Rankine cycle and trilateral flash cycle.

Using low to moderate grade heat source to convert the heat into electricity is very efficient and cheap technology. It is a sustainable energy source and unexploited application to generate power. The research indented to focus on using binary fluid (isobutane or iso-pentane) with the reaction turbine for the power generation purpose. This binary fluid has a lower boiling temperature comparing to the water at the atmospheric pressure. Rankine cycle and trilateral flash cycle can be examined by changing the flow rate of the binary fluid. This research would help to develop a heat engine that would use a simple reaction turbine to increase the energy conversion efficiency of a geothermal power plant. The application of this research is using hydrothermal resources as sufficient renewable energy recourse. This developed system can be implemented in Victoria by drilling down 5 km depth and targeting a temperature between 80 to 130 ºC.

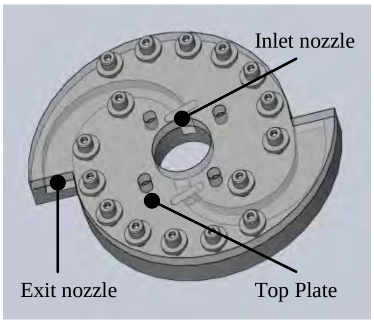


Fig 1: The proposed design of reaction turbine rotor

The practical project aims to achieve low cost and more efficient system to increase the total performance of power generation using the geothermal resource. Also, this research has to examine and model the most suitable cycle with the reaction turbine. This model compares the theoretical expectation with the empirical results outcome. The model has a concept to examine a simple reaction turbine to increase the efficiency of the system.

Keywords: Geothermal Energy, Sustainable Renewable Energy, Reaction Turbine, Binary Fluid

MAKING CARBON CAPTURE CHEAP AND ENVIRONMENTALLY FRIENDLY

Student: Hendy Thee **Display No.: 06**

Email Address: hkthee@unimelb.edu.au

Enrolled for: PhD **Status:** 3rd year

Tertiary Institution: The University of Melbourne

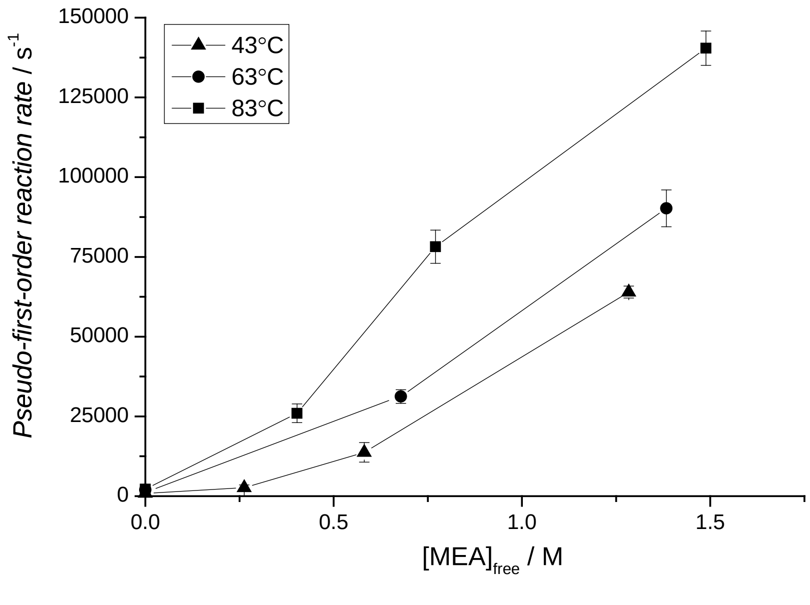
Department: Chemical and Biomolecular Engineering

Supervisors: Professor Geoff Stevens, Professor Sandra Kentish, Dr Gabriel da Silva

Phone: +61 3 8344 6621 **Email:** gstevens@unimelb.edu.au

Project Summary:

Aqueous solutions of potassium carbonate have gained widespread acceptance as viable solvents for pre- and post-combustion capture of carbon dioxide (CO_2). However, due to poor reaction kinetics a rate promoter is considered essential to improve the rate of CO_2 absorption. Using a well characterized wetted-wall column, we have evaluated the reaction kinetics of CO_2 absorption into a K_2CO_3 solution promoted with monoethanolamine (MEA). Results presented here show that at 63 °C the addition of MEA in small quantities, 1.1 M (5 wt%) and 2.2 M (10 wt%), accelerates the overall rate of absorption of CO_2 in a 30 wt% potassium carbonate solution by a factor of 16 and 45 respectively. The Arrhenius expression for the reaction between CO_2 and MEA is k_{MEA} [M^{-1} s^{-1}] = $4.24\times10^{9}\exp(-3825/T$ [K]) where the activation energy is 31.8 kJ mol^{-1}. Incorporating our experimental results into Aspen Plus™, we have developed an E-NRTL model that can replicate pilot plant and simulate industrial capture processes employing K_2CO_3 promoted with MEA as the capture agent.



Plot of pseudo-first-order reaction rate constant k_{obs} versus concentration of free amine $[MEA]_{free}$ at 43 °C to 83 °C.

THE DOMESTICATION OF ALGAE FOR GREEN ENERGY

Student: Simon Takouridis **Display No.: 07**

E-mail Address: s.takouridis@student.unimelb.edu.au

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: University of Melbourne **Department:** Chem & Biomolecular Eng

Supervisor: Dr Greg Martin **Phone:** +61 3 8344 6613

E-mail: gjmartin@unimelb.edu.au

Project Summary:

Algae are single celled plants that use sunlight as an energy source and the CO_2 from air for its food source. A great thing about algae is that they can produce and accumulate oil droplets within their cells. They can also be farmed in ponds where the cells are harvested and have the oil extracted and converted it into fuel that feeds directly into our existing transportation system. To give an idea of the potential, an area the size of South Australia could completely satisfy our current world demand for oil. These algae farms can be placed in desert land, using sea water and natural sunlight, all of which Australia has in abundance.

Another point about algae which is of importance is that fact that algae can actually be a highly nutritious meal. This can be extremely important for communities that are prone to starvation whereby they usually reside in areas where crops cannot grow well, but algae can. This would empower these communities to be self-reliant. It is obvious that nobody would enjoy eating algae however it is an easy choice when faced with starvation. Surely food technologists could develop a recipe that is more palatable.

Why do we not see South Australia covered with algae farms? This is because it is not economically viable as of yet. A key reason is the algae are adapted to the wild and not adapted for farming conditions and therefore they are not productive enough. Much like how wheat was domesticated for farming thousands of years ago, we need to do the same for algae. My research involves establishing foundation methods for the domestication of algae. This would occur via selecting the best performers in a population and taking them forth into the next generation, which over time results in an overall improvement of the cells.

Though unlike wheat, this process can be greatly accelerated in algae because they are microscopic and therefore the best performers can be selected from literally billions of cells which can all fit in a single laboratory tube. This is vastly different from selecting from a crop with only thousands of individuals. Also, algae reproduce very quickly and have generation times in just hours, rather than months as is typical with crops, therefore with more generations in a given time frame, adaptation is faster. The selection of improved algal cells can be very efficient whereby simply incubating them in an appropriate environment will select for the best performers because they will grow faster than the rest and therefore overpopulate the culture. This process is immensely superior to that of physically inspecting and selecting individual plants for signs of better productivity.

To date, the feasibility of the project has been established along with the development of detailed methods for this engineering endeavour. Currently, the domestication strategy employed is being tested with results establishing proof-of-concept expected in the coming months.

VICTORIAN BROWN COAL AS A FUEL FOR DIRECT CARBON FUEL CELLS

Student: Adam Carl Rady **Display No.:** 08

Email Address: adam.rady@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisors: A/Prof S Bhattacharya, A/Prof B Ladewig, Dr S Badwal, Dr S Giddey

Phone: +61 3 9905 9623 **E mail:** sankar.bhattacharya@monash.edu

Project Summary:

Coal fuels almost 40% of the world's power generation. Brown coal meets over 75% of the power generation needs in Victoria, which at the current consumption rate has over 500 years of resources. However, there is a global desire for alternative, less CO_2-intensive forms of power generation.

Direct carbon fuel cells (DCFCs) operate at high temperatures (typically 600 – 900 °C) and are capable of achieving overall system efficiencies of greater than 70%. They are also the only fuel cell capable of operating on a solid fuel, such as coal. Despite this, fuels trialled within the solid oxide DCFC has been limited primarily to carbon black, a pure carbon source with predictable properties. There is a need to trial more diverse and readily available fuels, which are likely to be future fuels for large-scale DCFC operation.

Brown coal chars are known to be reactive, have low ash content, and in theory could be a suitable fuel for DCFCs. However, the effect of the presence of mineral matter and solid trace metals in char on electrochemical performance is unknown. This project addresses these and other related issues and has a focus on fuel pre-treatment requirements. Chars to be investigated within the DCFC include raw coal chars, demineralised coal chars and chars impregnated with various ionic species.

Gasification of the fuel via the Reverse Boudouard reaction is known to occur at temperatures above 700°C, resulting in a change in rate-controlling mechanisms (illustrated in Figures 1 and 2 below) and consequently cell performance. The operating temperature of this fuel cell is a key design consideration and any mineral matter-related catalytic effects which lower the temperature of this mechanism shift warrants investigation.

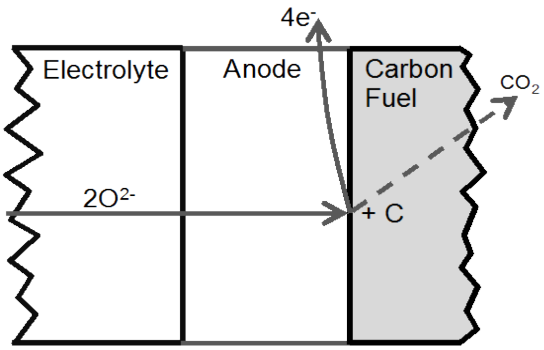


Figure 1: Mechanism for carbon consumption in a solid oxide DCFC < 700°C

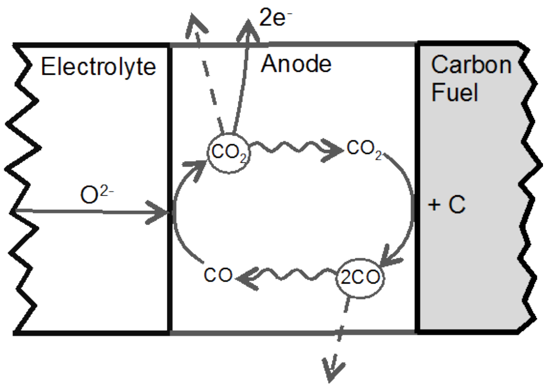


Figure 2: Mechanism for carbon consumption in a solid oxide DCFC > 700°C

This research is a collaborative project between Monash University and CSIRO, funded by Brown Coal Innovation Australia (BCIA), and may be classified as an 'embryonic" R&D.

LIGHT ASSISTED WATER ELECTROLYSIS ON DYE/CONDUCTING POLYMER BLENDS

Student: Chun Hin Ng **Display No.:** 09

Email Address: chun.ng@monash.edu

Enrolled for: PhD **Status:** 1st year

Tertiary Institution: Monash University **Department:** Materials Engineering

Supervisor: Associate Professor Bjorn Winther-Jensen

Phone: +61 3 9905 5343 **E mail:** bjorn.winther-jensen@monash.edu

Project Summary:

Conversion to a hydrogen based economy is an often touted solution for climate change though major hurdles need to be overcome. An important first step is addressing the production of hydrogen itself; current methods rely on steam reformation and while cheap it consumes valuable fossil fuels and produces harmful CO_2. An alternative to this is to pair renewable energy with water electrolysis, a process where electricity is used to split water to produce H_2 and O_2[1]. Unfortunately the need for expensive catalytic electrodes (Platinum) and harsh chemical environments have limited and will continue to limit electrolysis as a viable hydrogen production method. In light of this, we attempt to tackle the problem by investigating cheaper electrode materials based on intrinsically conductive polymers (ICPs) as an alternative to Pt[2].

Typically when cheaper materials are used the voltage requirements for electrolysis become prohibitively high so our system is designed to harness extra energy from light to photocatalyse the reaction. Blending an ICP with an organic dye, the working principles of the electrode draw on concepts from dye sensitized solar cells (DSSC) and organic solar cells and is illustrated in the below figure. From DSSC we borrow the idea of utilising dyes' light absorption to harvest energy from photons while from organic solar cells, we rely on the quick charge separating abilities of various ICP's such as PEDOT to prevent recombination.

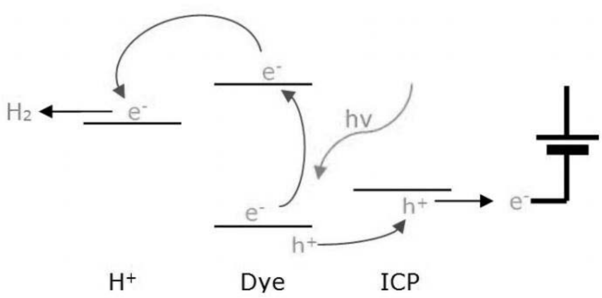


Figure 3: Schematic of the electrode's working principle

The use of polymers and organic dyes in the electrode also brings its own unique advantages. Apart from lower cost and environmental friendliness, organic materials have the ability to be modified at a molecular level and allows for customised properties. Since the effectiveness of the electrode is very much dependent on the correct positions of energy levels, this ability becomes invaluable. By studying how small variations in the dye's structure affect the molecule's energy levels, we can fine-tune the electrode for optimal performance.

[1] K. Rajeshwar, R. McConnell, S. Licht; Solar Hydrogen Generation, Springer New York (2008)
[2] Winther-Jensen, Bjorn et al.; Adv. Mater. 2010, 22, 1727–1730

‘NANO-FLOWERS’ TO CAPTURE CARBON DIOXIDE

Student: Andri Halim **Display No.: 10**

Email Contact: ahalim@co2crc.com.au

Enrolled for: PhD **Status:** 3rd year

Tertiary Institution: University of Melbourne **Department:** Chemical & Biomolecular Eng

Supervisor: Prof. Greg Qiao / Prof. Sandra Kentish

Phone: +61 3 8344 8665 +61 3 8344 6682 **Email:** gregghq@unimelb.edu.au / sandraek@unimelb.edu.au

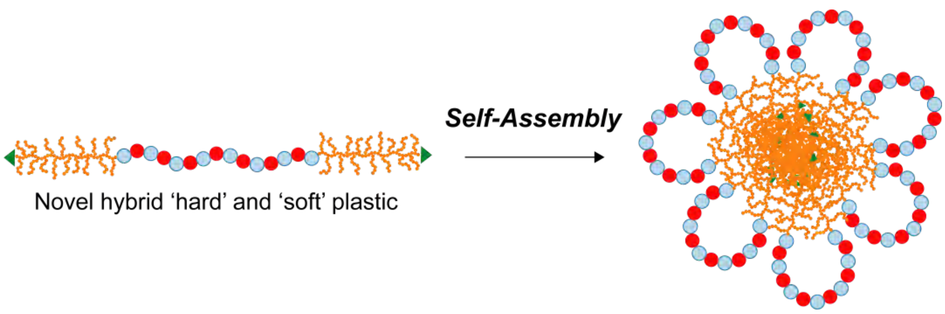
Project Summary:

Global warming is one of the major environmental problems facing the world today. Over the last century, the global average temperature has increased 0.6 ± 0.2°C and a great deal of effort is being undertaken to reduce these greenhouse gas emissions. Carbon Capture and Storage (CCS) involves capturing, purifying, compressing, transporting and storing CO_2 that would otherwise be emitted to the atmosphere. It has been reported that the cost of capturing CO_2 contributes approximately 80% to the total cost of CCS. Hence, developing an efficient and economical way of separating CO_2 from a mixture of gases is essential.

Membrane technology offers advantages for carbon capture such as simple operation, low capital cost and the ease of scale up. There are two main criteria for the membrane selection. These are a high rate of flow through the membrane (permeability) and the ability to separate carbon dioxide from the other gases (selectivity). However, it has been shown that there is a general trade-off between permeability and selectivity; membranes that have high permeability tend to have low selectivity and *vice versa*. Current research is heavily focused on breaking this nexus in order to improve efficiency and reduce capture costs.

In this project, a novel hybrid material consisting of hard and soft polymer regions has been developed. The hard polymer (or plastic) is generally rigid in nature and provides the selective separation of the target gas from other gases. It also provides the structural and mechanical support that is necessary. One example of a high performance hard plastic is polyimide and it has been chosen for this project. The introduction of a soft plastic allows for the formation of discrete and ordered supramolecular domains within the membrane. Poly(dimethylsiloxane) (PDMS) is used for this purpose – this plastic has received considerable attention in gas membrane research as it is flexible and can greatly increase the rate of gas flow through the membrane.

A series of novel hybrid membranes containing ‘hard’ and ‘soft’ plastic segments have been developed. Molecular organization of these plastics leads to ‘nano-flowers’ with PDMS as the core surrounded by polyimide ‘petals’. These results demonstrate the ability of such plastics to re-organize themselves to form localized, high permeability, soft nanodomains within a hard plastic matrix, which in turn could lead to increases in separation performance and reduced capture costs.



TOWARDS A MORE HOLISTIC ENERGY ASSESSMENT OF RESIDENTIAL BUILDINGS - A MULTI-SCALE LIFE CYCLE ENERGY ANALYSIS FRAMEWORK

Student: André Stephan **Display No.: 11**

Email Address: astephan@student.unimelb.edu.au

Enrolled for: Joint-PhD **Status:** 2nd year

Tertiary Institutions: (1) The University of Melbourne (2) Université Libre de Bruxelles

Departments: (1) Faculty of Architecture, Building & Planning (2) BATir: Building, Architecture & Town planning

Supervisors: (1) Dr. Robert Crawford (2) Prof. Kristel de Myttenaere

Phone: +61 3 8344 8745 **E mail:** (1) rhcr@unimelb.edu.au (2) Kristel.De.Myttenaere@ulb.ac.be

Project Summary:

Background:

- Buildings are directly responsible for 40% of final energy consumption in most developed economies and for much more if indirect requirements are considered. This results in huge impacts which affect the environmental balance of our planet.
- However, most current building energy assessments focus solely on operational energy, overlooking other energy consumption such as embodied and transport energy. Embodied energy comprises the energy requirements for building materials production, construction and replacement. Transport energy represents the amount of energy required for the mobility of building users.
- Recent studies have shown that embodied and transport energy demands often represent more than half of the total life cycle energy consumption of residential buildings. Hence, current assessment tools and policies overlook more than 50% of the life cycle energy use. Decisions based on partial assessments might result in an increased energy demand during other life cycle stages or at different scales of the built environment.

Aim:

The aim of this research is to develop a comprehensive life cycle energy analysis framework, usable by building designers, decision makers and researchers, to assess the total energy use and greenhouse gas emissions associated with residential buildings, over their useful life.

This framework takes into account energy requirements at the building scale, i.e. the embodied and operational energy demands, and at the city scale, i.e. the embodied energy of nearby infrastructures and the transport energy of its users. The framework is implemented through the development, verification and validation of an advanced software tool (programmed in python and wxpython) which allows the rapid analysis of the life cycle energy demand of residential buildings and districts. Two case studies, located in Brussels, Belgium and Melbourne, Australia, are used to investigate the potential of the developed model.

Results:

- Each of the embodied, operational and transport energy requirements represent a significant share of the total energy requirements and associated greenhouse gas emissions.
- Current building energy efficiency regulations often result in a higher life cycle energy use. Other parameters, such as the house size, type, or location should be targeted by future policies to effectively reduce energy consumption and greenhouse gas emissions.
- The use of the developed tool will allow building designers, town planners and policy makers to reduce the energy demand and greenhouse gas emissions of residential buildings by selecting measures that result in net savings. This will ultimately contribute to reducing the environmental impacts of the built environment.

COMBUSTION BEHAVIOUR OF VICTORIAN BROWN COAL IN FLUIDIZED BED UNDER OXY-FUEL COMBUSTION CONDITION

Student:: Bithi Roy **Display No.: 12**

Email Address: bithi.roy@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University
Department: Dept of Chemical Engineering

Supervisor: A/Prof. Dr. Sankar Bhattacharya

Phone: +61 3 9905 9623 **E-mail:** sankar.bhattacharya@monash.edu

Project Summary:

Coal is a widely used fuel for power generation in Australia, accounting for about 80% of Australia's electricity production. Conventional coal-fired power generation technologies, however, emit a significant amount of conventional and trace pollutant gases. As CO_2 emission is one of the major environmental issues, there is a need to develop advanced technologies that either reduces these emissions while maintaining high plant efficiency and/or makes easier capture of CO_2 from coal-fired power plants. Oxy-fuel combustion is one such technology for power generation from coal due to its ability to produce highly concentrated CO_2 in the flue gas, which in turn allows easier and cheaper CO_2 separation from flue gas. For this reason, Oxy-fuel technology has been considered a very promising alternative to conventional air-fired combustion. When this technology is introduced to the well established fluidized bed combustion, it offers some additional advantages, such as fuel flexibility, uniform temperature distribution, low NO_x emissions due to low operating temperature and potential for in-bed SO_2 capture via addition of sorbent. Hence, a combination of these two technologies – Oxy-fuel based fluidized bed (Oxy-FB) combustion - is an emerging technology for power generation using different grades of coals including brown coals/lignites. Although few studies have addressed the Oxy-FB combustion of lignites, its applicability using Victorian brown coal has remained unexplored. Since Victoria has large reserves of brown coal, estimated at 430 billion tonnes, successful application of a technology like Oxy-fuel fluidized bed can make a significant difference to the utilization of this coal for power generation with easier CO_2 capture. This project aims to investigate the issues related to application of Oxy-FB combustion using Victorian brown coal.

The project is a combination of experimental and modelling work. Experiments are carried out in bench-scale fluidized bed reactors – quartz reactor (of around 500 mm high and an inner diameter of 40 mm) and stainless steel reactor (0.1 m in diameter and 3.5 m in length). During the experiments the generated gases are continuously analysed using gas analyser, whilst the solid residues are characterized using different analytical techniques including X-ray Fluorescence (XRF) and Scanning Electron Microscopy (SEM). The experimental work involves assessing combustion performance, and agglomeration and sulphation characteristics of Victorian brown coal in fluidized bed during Oxy-fuel combustion condition. In this presentation, the effects of oxygen and steam in the combustion atmosphere, and combustion temperature on flue gas composition and trace elements distribution are considered. Furthermore, results of predictions using thermodynamic equilibrium modelling are also presented to compare with the experimental results. All these results are important for selection of operating conditions for Oxy-fuel fluidized bed combustion using Victorian brown coal.

INVESTIGATION OF INORGANIC METAL OXIDES AS CATALYSTS FOR PHOTO-ELECTROCHEMICAL WATER SPLITTING

Student: Fengling Zhou **Display No.: 13**

Email address: Fengling.zhou@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University **Department:** School of Chemistry,

Supervisors: Prof. Leone Spiccia and Prof. Douglas R. Macfarlane

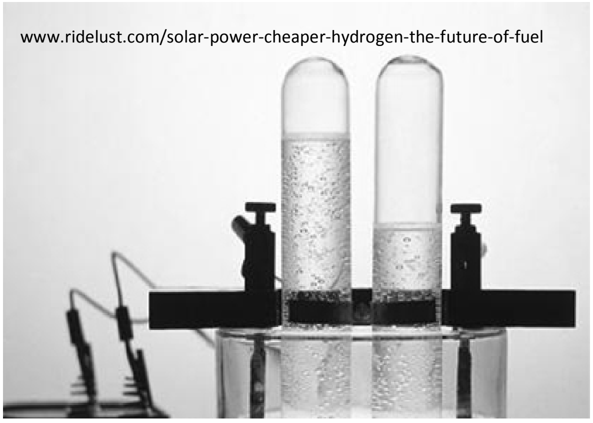
Emails: leone.spiccia@monash.edu / douglas.macfarlane@monash.edu

Project Summary:

Hydrogen (H_2), the fuel with the highest energy capacity per unit mass, is considered to be a potential candidate for a non-polluting energy source due to its environmental friendly and renewable characteristics.[1] Water splitting is a promising method to produce hydrogen through decomposition of water.[2, 3] the photo-assisted production of hydrogen and oxygen from water potentially offers an extremely promising way for clean, low-cost and environmentally friendly conversion of solar into chemical energy.[1] However, solar hydrogen production from water has been hampered by a lack of efficient catalysts, made from earth-abundant elements. Many efforts have been directed in recent years to the development and characterization of new types of photo-electro-catalysts for water splitting. [4, 5]

This project aims to develop low-cost, high efficiency photo-electro-catalysts based on earth-abundant elements for catalytic water splitting. Firstly, the catalytic activity is determined by the chemical composition and micro-morphology of the catalysts. This research focuses on exploring the correlation between the electro-catalytic activity and the chemical composition and microstructure, and optimizing the catalysts, by investigating the influence of synthesis parameters, such as electrodeposition electrolytes, [6] additives and post treatment.

Secondly, by coupling a light harvesting material with the electro-catalyst, the catalytic water splitting could be highly enhanced by illumination. Based on the optimized electro-catalysts above, this research focuses on developing photo-electrochemical (PEC) devices by introducing a porous supporting structure with high surface area, and light-harvesting materials.



Reference

[1] E. Selli, G. L. Chiarello, E. Quartarone, P. Mustarelli, I. Rossetti, L. Forni, *Chem. Comm.* **2007**, 5022.

[2] S. U. M. Khan, M. Al-Shahry, W. B. Ingler, *Science* **2002**, *297*, 2243.

[3] J. L. Dempsey, A. J. Esswein, D. R. Manke, J. Rosenthal, J. D. Soper, D. G. Nocera, *Inorg. Chem.* **2005**, *44*, 6879.

[4] M. W. Kanan, D. G. Nocera, *Science* **2008**, *321*, 1072.

[5] D. K. Zhong, D. R. Gamelin, *J. Am. Chem. Soc.* **2010**, *132*, 4202.

[6] F. L. Zhou, A. Izgorodin, R. K. Hocking, L. Spiccia, D. R. MacFarlane, *Adv. Energy Mater.* **2012**.*2*,1013.

PHOTO-SWITCHABLE METAL ORGANIC FRAMEWORKS FOR CARBON CAPTURE

Student: Richelle Lyndon **Display No.: 14**

Email Address: Richelle.Lyndon@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University **Department**: Chemical Engineering)

Supervisor: A/Prof Bradley Ladewig and Dr Matthew Hill

Phone: +61 3 9905 1995 / +613 9545 2841

E mail: Bradley.Ladewig@monash.edu / Matthew.Hill@csiro.au

Project Summary:

With carbon dioxide (CO_2) emission becoming an increasing concern globally, there are key limitations in using conventional post-combustion carbon dioxide capture technology. The process typically involves adsorption of CO_2 by pressure, temperature or vacuum swings, which can increase the energy requirements of a coal-fired power plant up to 40%. As triggering CO_2 release using heat and vacuum is cost- and energy- intensive, it is highly desirable to develop an economically viable solution using new stimuli.

Light, particularly concentrated sunlight, is an attractive stimulus for CO_2 capture and release. If used with a suitable adsorbent, it may significantly reduce the cost of operation. A promising candidate as adsorbents is Metal Organic Frameworks (MOFs), a microporous crystalline material consisting of metal centers and organic linkers that display extreme porosity and surface area, high gas-uptake capacity and selective CO_2 adsorption. Currently, the project aims to develop light-responsive MOFs as a novel route for low-cost renewable CO_2 capture and release.

In this work, a light-responsive azobenzene-based MOF has been successfully proven to show dynamic photo-switching property during gas adsorption. The process is like wringing out a sponge, whereby exposure to light, including broadband UV similar to solar sources, can instantaneously release up to 69% of CO_2 adsorbed. This is due to the oscillation of the light-responsive groups in the MOF framework between native and excited states. Since the process is reversible, employing the light-responsive MOF in post-combustion carbon dioxide capture technology could minimise the energy for adsorbent regeneration and maximise CO_2 capture efficiency. With a patent pending status, such exciting results could advance the urgent development of low fossil fuel-generated energy.

IMPLEMENTATION OF RENEWABLE ENERGY TO REDUCE CARBON TAX AND FUEL CELL AS A BACK-UP POWER FOR NATIONAL BROADBAND NETWORK

Student: Kannan Jegathala Krishnan **Display No.: 15**

Email Address: Kannan.Jegathala-Krishnan@vu.edu.au

Enrolled for: PhD **Status:** 3rd year

Tertiary Institution: Victoria University **Department:** School of Engineering & Science

Supervisor: Professor Akhtar Kalam

Phone: +61 3 9919 5504 **E mail:** akhtar.kalam@vu.edu.au

Project Summary:

A reliable power is paramount and loss of power to communication equipment can mean loss of service to customers and loss of millions of dollars to industries. When called upon power at telecom sites ideal choice being diesel generator requires fuel storage, produce combustion emissions, noisy and maintenance costs are high. The valve regulated lead –acid battery banks (VRLA) prone to self-discharge, need replacement every 3 years, are bulky, heavy and costly to maintain. New battery technologies, ultra capacitors and flywheels have been employed recently but disadvantage of each technology are significant. P-21 GMBH (Germany), Dantherm Power A/S (Denmark), Plug Power Inc. (USA) and Hydrogenics (Canada) are some of the companies already offering Fuel Cell back-up power by using H_2 bottles and it is expensive to run distance trucks requiring several site visits per year carrying H_2 bottles to a rural site. Recent collaboration between Victoria University, Sustainable Energy Fuel Cells Australia (SEFCA) and ACTA Energy has resulted in thorough laboratory testing for H_2 generation and data compilation of Fuel Cells in Power Systems Research Laboratory at Victoria University is discussed in this presentation. The H_2 Generator and PEM Fuel Cell system generates H_2 on-site and is capable to compete with traditional technologies and can be implemented as a back-up power in telecommunication system where there will be need for a reliable back-up power supply.

Also, climate is changing; greenhouse gas emissions from human activity are the major cause for global warming. To avoid the increased costs of delaying action on climate change, cut carbon pollution, drive Australian innovation and to reshape economy the Australian Government is building a Clean Energy Future (Carbon price, Energy efficiency, Renewable energy and Land use). This presentation suggests that the use of Solar/Wind 4kW micro-generation system is capable to reduce CO_2 emissions by implementing in every independent home in Australia. This project examines the energy produced by the Solar/Wind 4 kW micro-generation system and energy consumed in a 3 Bedroom Hall Kitchen Residence in Footscray, Melbourne and various readings of monthly, weekly, daily and partially curves are recorded at regular intervals.

The benefits of this project are directed towards the **Australian National Broadband Network (NBN)** where there will be need for a reliable back-up power supply since NBN will be rolling out to several hundred points of presence (POP's) and also the Australian Government's comprehensive plan for securing a **Clean Energy Future.**

ENTRAINED FLOW GASIFICATION OF BROWN COAL – A COMPARISON OF SLAG VISCOSITY MODELS

Student: Sunaina Dayal **Display No.: 16**

Email Address: sunaina.dayal@monash.edu

Enrolled for: M Eng Sc **Status:** 1st year

Tertiary Instituition: Monash University **Department:** Chemical Engineering

Supervisors: A/Professor Sankar Bhattacharya / Professor Klaus Hein

Phone: +61 3 9905 9623 **Email:** sankar.bhattacharya@monash.edu
Klaus.Hein@monash.edu

Project Summary:

Victoria has large reserves of brown coal. These low rank coals are currently used as a fuel for power generation. One of the major options for hydrogen or chemicals production and less energy intensive CO_2 capture is gasification. Coal gasification can be implemented over a vast range of temperatures, each temperature range posing unique problems that need to be identified and explored in detail.

There exist three major types of gasifiers for gasification of coal - fixed bed, fluidised bed and entrained flow. Due to the friable nature of brown coal, fixed bed gasifiers are not suitable. Fluidised beds suffer from low carbon conversion. Entrained flow gasifiers, on the other hand, are commercially available for gasification of black coals. These gasifiers are more suitable for operation at high temperature. A continuous outflow of slag is required to maintain uninterrupted operation of an entrained-flow gasifier. Excessive build-up of slag melt on the refractory wall reduces heat transfer, causing gasifier downtime or shutdown. Therefore, the liquid slag viscosity must be low enough for slag to be removed from the gasifier in molten form.

Therefore, information for efficient gasifier operation, such as composition, viscosity, and the change of viscosity with temperature for coal ash slags is essential. However, this information is largely unknown for Australian brown coals. Furthermore, the existing viscosity models are mainly developed based on bituminous coals. This project aims to generate this information, develop surface tension and viscosity models, compare these predictions through controlled measurements, and modify the existing models for application with brown coals. Some modelling work of slag composition for three brown coals has been carried out using a thermodynamic software package, FactSage. This paper presents the results of the preliminary work, a review of the existing models, their comparison with this work, and sets the direction for ongoing work.

INTER-SEASONAL THERMAL STORAGE

Student: Tshewang Lhendup **Display No.: 17**

Email Contact: t.lhendup@student.unimelb.edu.au

Enrolled for: PhD **Status:** 3rd year

Tertiary Institution: University of Melbourne **Department:** Infrastructure Engineering

Supervisor: A/Prof. Lu Aye and A/Prof. R. J. Fuller

Phone: +61 3 8344 6879 **Email:** lua@unimelb.edu.au

Project Summary:

Diminishing fossil fuel sources and increasing greenhouse gas (GHG) emissions are the main driving forces behind the efforts to use more renewable energy. The biggest drawback of renewable energy is the source which is both intermittent and irregular in nature. Therefore thermal energy storage (TES) is necessary to ensure that the energy is available when it is needed. This study investigates the performance of an inter-seasonal thermal storage integrated with a heat pump and unglazed solar collectors. The proposed system uses separate ground storage to store heat mainly collected in summer and coolth in winter for use in winter and summer respectively. An unglazed collector, which is cheaper than the conventional solar thermal collector is used to collect solar energy during the day and for dissipating heat by sky radiation during the night.

Aim:

The aim is to identify optimal design and operational parameters of an inter-seasonal thermal storage integrated with heat pump and unglazed solar collectors.

Methodology:

This research focuses on the development of TRNSYS models and validation with the experimental results. The validated models will then be used to assess the potential of the proposed system in a typical three bedroom residential house in Melbourne. The models will further be used to assess the potential for a cluster of houses in different climate zones in Australia. The experimental rig was designed and set up at the University of Melbourne, Burnley campus. A total of four in-situ thermal response tests were conducted in March and the coolth charging experiment has been conducted from July to September.

Experimental results:

- The thermal conductivity of the ground is estimated to be 2.25 W m-1K-1 for the heat storage borehole and 2.22 W $m^{-1}K^{-1}$ for the coolth storage borehole.
- The undisturbed ground temperature is measured to be 17.1°C for coolth storage borehole and 17.3°C for heat storage borehole.
- It is able to reject up to 85 W m^{-1} in the heat storage borehole heat exchanger and 100 W m^{-1} in the coolth storage borehole heat exchanger.
- An unglazed solar collector of 8 m^2 is able to achieve a mean cooling power of 120 W m^{-2} during experiments from 1st July to 30th September.

Simulation results:

- TRNSYS simulations show that by recharging the ground, the borehole length can be
- reduced by up to 32% for heat storage and 23% for coolth storage for the same coefficient of
- performance for the heat pump.
- The annual storage efficiency is 0.93 and 0.83 for heat and coolth storage respectively.

ENERGY EFFICIENCY ENHANCEMENT OF DATA CENTERS USING COLD AISLE CONTAINMENT

Student: Ali Habibi Khalaj **Display No.:** 18

Email Address: alih@student.unimelb.edu.au

Enrolled for: PhD **Status:** 1st year

Tertiary Institute: University of Melbourne **Department:** Mechanical Engineering

Supervisor: Prof. Saman Halgamuge

Phone: +61 3 8344 5587 **Email:** saman@unimelb.edu.au

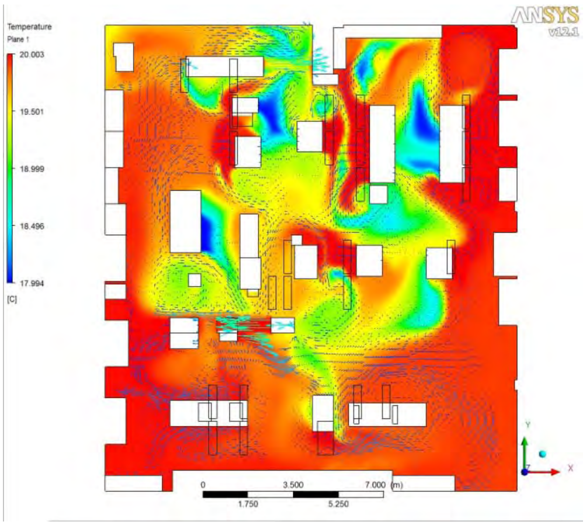
Project Summary:

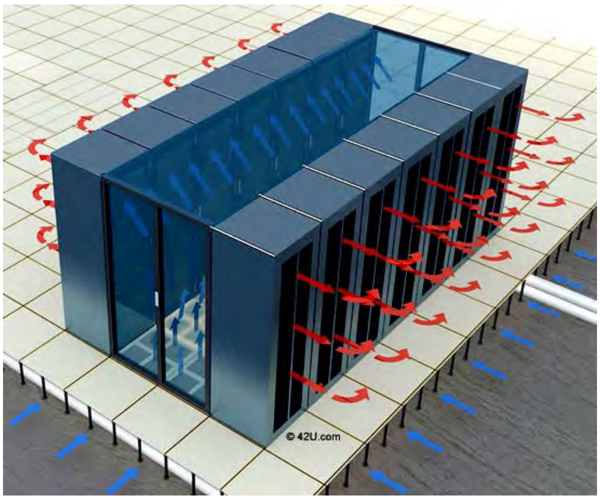
Data Center (DC) is a computing infrastructure facilities housing large amounts of IT equipment required to process, transmit and store information. Uninterrupted and zero-downtime operation of DCs is the most crucial requirement for all DCs. Power and cooling are two crucial factors in this regard. Uninterrupted power is assured by installing several backup sources of power that would be automatically brought on line as soon as a power failure is detected. But, cooling is a more complex issue, since it must maintain the temperature and humidity of a DC in a proper condition according to the available standards.

According to report of the United States Environmental Protection Agency (EPA), DCs consume 1-2% of today's world electricity production and due to the high demand for these resources; it is increasing at a rate of 12% per year. In addition, considerable fraction of operational costs of a typical DC, account for 20–50% of total energy consumption of DC's facilities, can be ascribed to its cooling system. Therefore, since energy consumption of the DCs' cooling system has been considered as a growing concern of all DCs, thermal management of DC has became a focus of DCs' managers and researchers in the recent years.

Thermal management solutions of DCs could be considered in multi-level: chip level, server level, chassis level, rack level, plenum level and room level. The solutions for each level could be considered as short and long term from the viewpoint of implementation and payback. For instance, majority of the solutions for chip, server, chassis and rack levels are considered as long-term, since their implication requires considerable modifications with sizeable capital investments that may only be viable for about half the DCs during their significant facility renovations. On the other hand, solutions for room and plenum level are considered as short-term due to their less modification in DC, easy installation and low investment. Hence, since they are more interesting for industry, short-term solutions are considered in this project.

It can be mathematically shown that more than 30% of the electricity used for DC's cooling is wasted due to inherent inefficiency in the room level, in which considerable amount of energy could be saved via elimination of this inefficiency. In this project, containment of cold aisle, as one the thermal management solutions, has been considered in order to increase the efficiency of air distribution inside the DC.





BIOMASS CONVERSION IN ENTRAINED FLOW REACTOR FOR CLEANER POWER GENERATION

Student: Kawnish Kirtania **Display No.: 19**

Email Address: kawnish.kirtania@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: A/Prof Sankar Bhattacharya

Phone: +61 3 9905 9623 **E mail:** sankar.bhattacharya@monash.edu

Project Summary:

Biomass is a major renewable fuel to replace CO_2 emission intensive fossil fuels. Biomass can be converted both biochemically and thermo-chemically to fuel gas for liquid fuels or chemicals production. However, biochemical conversion is a much slower process than thermo-chemical conversion. Among the different methods, thermo-chemical conversion using pyrolysis and gasification is potentially a cleaner and more efficient alternative than combustion.

As a newer source of energy, non-conventional algal biomass shows prospect for its high growth and CO_2 capture capability. However, algae needs in depth research for its thermochemical conversion whereas woody biomass has been studied extensively. A comparative study of several woody and algal biomass would be made in this study by thermochemical conversion over a range of temperature.

The project has the following objectives:

- Thermochemical conversion of three woody biomass (two kinds of sawdust, coconut shell) and one algal biomass and establish the yield of solids, liquids and gaseous components as a function of temperature and particle size
- Characterize the solids, liquids and gaseous components including pollutants using a range of spectroscopic and microscopy techniques
- Establish and compare the kinetics of pyrolysis and gasification of the woody and algal biomass

ASSESSMENT OF DIMETHYL ETHER SYNTHESIS FROM VICTORIAN BROWN COAL

Student: Bayzid Kabir Kazi **Display No.: 20**

Email Address: bayzid.kazi@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: A/Prof. Sankar Bhattacharya

Phone: +61 3 9905 9623 **E mail:** Sankar.bhattacharya@monash.edu

Project Summary:

Victoria has the largest brown coal reserves in the world. It is the cheapest source of primary energy and used as a fuel for baseload power generation in Victoria. However, high moisture content in as-mined coal results in low efficiency and high CO_2 emission during power generation. The high moisture makes coal drying necessary, however the high reactivity of the dried coal has prohibited its export and wider use outside mine-mouth power plants. Alternative processing paths leading to liquid fuels and chemical production can provide export market for brown coal derived products, and more energy efficient application of brown coal. Gasification is an alternative processing path that can be used for production of liquid fuels, chemicals or power..

Dimethyl ether (DME) is a non-toxic, non-carcinogenic and non-corrosive compound. Though, it is being used as an aerosol propellant for a long time, recent focus on DME is because of its use as transport and household fuel. Therefore, synthesis of DME from brown coal could be an attractive option because of its environmentally benign properties and wide range of applications. However, to choose this process path of conversion research on brown coal gasification and syngas to DME conversion is necessary. Gasification of brown coal producing syngas suitable for DME synthesis and catalyst development for syngas to DME is therefore the major focus of this research.

This current project involves:

- Gasification of Victorian brown coal under a range of temperature in small instruments to bench scale reactors.. Results from the gasification experiments set the basis for the feed gas composition for the DME synthesis experiments
- Screening of commercial methanol synthesis catalysts for DME synthesis
- Development and synthesis of novel catalysts for high yield and selectivity of DME production using representative fuel gas from brown coal gasification
- Performance of catalysts in presence of conventional pollutants in fuel gas, and identify the extent of gas clean-up necessary following brown coal gasification
- Development of a steady-state model for process integration and optimisation of the DME synthesis incorporating drying, gasification, gas clean-up and DME synthesis

The experimental work on DME synthesis is being performed in a continuous flow high-pressure DME synthesis rig. This is complemented by electron microscopy and synchrotron based characterization of the catalysts.

TRIGEN: A HOLISTIC APPROACH FOR OPTIMISED GENERATION OF HEATING, COOLING AND ELECTRICITY FOR BULK ENERGY CONSUMERS

Student: Saliya Jayasekara **Display No.: 21**

Email Address: jgaj@student.unimelb.edu.au

Enrolled for: PhD **Status:** 3rd year

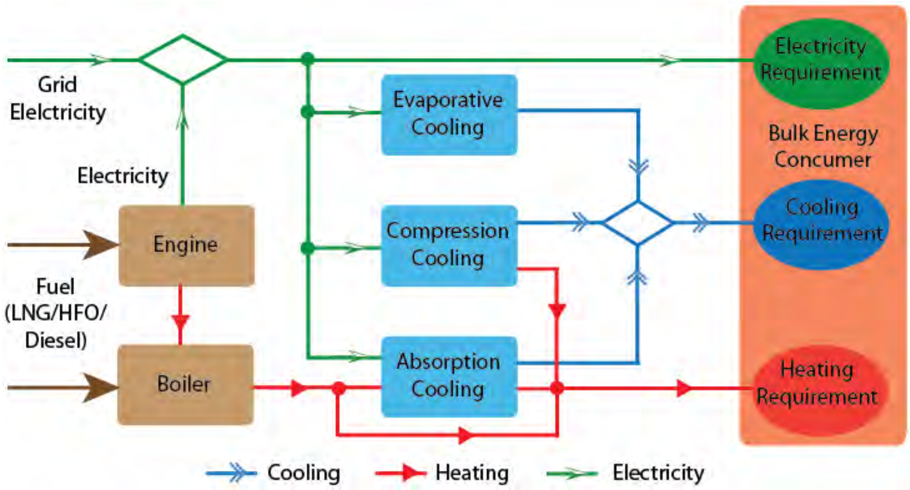
Tertiary Institute: University of Melbourne **Department:** Mechanical Engineering

Supervisor: Prof. Saman Halgamuge

Phone: +61 3 83445587 **Email:** saman@unimelb.edu.au

Project Summary:

Hospitals, hotels, universities and data centres are considered as bulk energy consumers with the need to use electricity, heating and air conditioning simultaneously. Mostly, electricity is the prime source of energy for air conditioning while natural gas is used for heating. The process of electricity production using natural gas or oil is inefficient as it involves the production of heat energy first which can only be converted into electricity with an efficiency of about 40% (combined cycle is around 52% with large investments). The remaining 60% is released into the environment as waste heat. The main concept of trigen or Combined Cooling, Heating and Power (CCHP) systems, that produce electricity, heating and cooling simultaneously, is based on the recovering of this waste heat.



The proposed engineering concept of the trigen system includes vapour absorption chillers, vapour compression chillers, evaporative coolers, generator and hot water/steam generator is illustrated in the figure. The electricity, mostly from the generator and from the grid when it is only required. Waste heat flows from the generator via boiler and absorption chiller while compression chiller also contributes with waste heat. Both the generator and compression chiller can be found on existing facilities of bulk energy users (hospitals, data centre, etc.). Overall system optimisation and reduction of energy usage not only reduces the costs but also improves the environmental sustainability. It reduces the carbon foot print of the facility and helps energy users to be greener. Proper selection of design and operation parameters of trigen systems is an important and challenging task. Optimisation of layout, capacity and operational parameters with the characteristics of load and seasonal changes are some of the main requirements for achieving these goals.

Moreover, the performance of the optimal sizing and operating strategies are evaluated using simulations and compared with well-known conventional strategies for long and short term operation plans. In order make the poster clear only the following two achievements are presented.

- Mathematical modelling and experimental verification of double effect LiBr absorption chiller
- Introduction of low temperature double effect absorption cycle (a novel method) to fill the gap of the firing temperature between 115 ^{o}C and 135 ^{o}C .

ONLINE OPTIMIZATION OF SPARK TIMING IN ALTERNATIVE FUELLED ENGINES

Student: Alireza Mohammadi **Display No.: 22**

Email Address: a.mohammadi@pgrad.unimelb.edu.au

Enrolled for: PhD **Status:** 3rd year of 4 year PhD

Tertiary Institution: University of Melbourne **Department:** Mechanical Engineering

Supervisor: A/Prof. C Manzie **Phone:** +61 3 8344 6731 **Email:** manziec@unimelb.edu.au

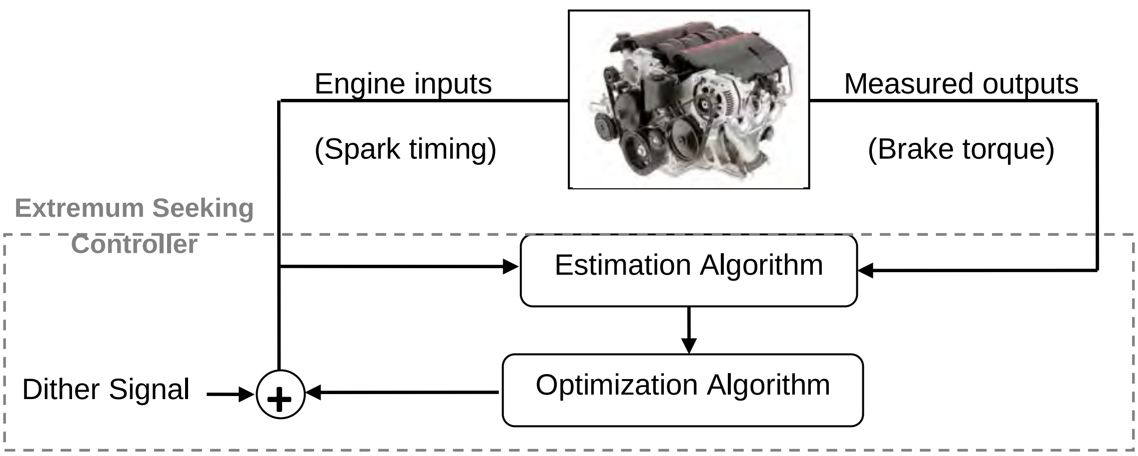
Project Summary:

Nowadays, due to the increasingly demanding emissions legislation and growing concerns about the shortage of petroleum resources, the research and development into alternative fuels for automotive application has become an important subject. Alternative fuels such as ethanol and methanol mixture, LPG (Liquefied Petroleum Gas), and CNG (Compressed Natural Gas) have lower fuel costs and cleaner exhaust gas emissions as compared with gasoline and diesel. These fuels may also enhance energy security through increasing sources of reliable energy.

However, despite all of these advantages, the main drawback of these fuels is that their composition can vary depending on origination, season, and relative cost. The results of a few studies established significant variations between supply sources within large geographic areas such as Europe and Australia.

The change in composition of these fuels was found to have a profound effect on performance and emissions of alternative fuelled engines. One reason is that current approaches to control of engines rely on static maps for steady-state operating points. In these methods, the optimum values of variables, such as spark timing and air/fuel ratio, are stored in a memory in engine control unit (ECU) for a finite number of engine operating set-points. The static maps must be robust enough to handle all possible fuel compositions, which implies detuning of closed-loop performance. Alternatively, the fuel composition must be sensed and calibration of the maps undertaken for all possible compositions. Consequently, the former approach results in suboptimal engine performance at any operating point, while latter involves more cost and calibration effort. Both are undesirable.

This points to the need for online adaption in order to optimize the engine performance as the mixture of fuel changes. Extremum seeking controllers typically provide online optimization in the presence of plant dynamics and slowly time-varying uncertainties. As a result, they warrant investigation as a potential solution to the fuel composition problem described above. Therefore, the objective of this project is to maximize the engine brake torque by finding the best spark timing using the extremum seeking controller in the presence of varying fuel composition, see the following figure.



A ROTATING RING-DISC STUDY INTO THE OXYGEN REDUCTION REACTION ON PEDOT ELECTRODES FOR FUEL CELLS AND BATTERIES

Student: Robert Kerr **Display No.:** 23

Email Address: Robert.kerr@monash.edu

Enrolled for: PhD **Status:** 3rd year

Tertiary Institution: Monash University **Department:** Materials Engineering

Supervisors: A/Prof. Bjorn Winther-Jensen, Prof. Maria Forsyth

Phone: +61 3 9905 3698 **E-mail:** bjorn.winther-jensen@monash.edu

Project Summary:

The prohibitively high cost and poor long-term stability of noble metal catalysts in polymer electrolyte membrane fuel cell (PEMFCs) has seen attention turn towards alternative electrocatalytic materials such as conducting polymers. Poly(3,4-ethylenedioxythiopene) (PEDOT) has emerged as one such candidate since the discovery by Winther-Jensen *et al.* of its ability to catalyse the cathodic oxygen reduction reaction (ORR) [1]. Here it was shown that PEDOT catalyses the ORR most effectively under alkaline conditions in a 4-electron process, making it particularly attractive for alkaline fuel cells (AFCs) and metal-air batteries/metal-air fuel cells. However, a seemingly contradictory report was recently published stating that the ORR proceeds *via* the undesirable 2-electron process for PEDOT electrodes [2].

The ORR is able to proceed *via* two overall pathways; the "direct" and the "series" pathways. The direct pathway sees the complete reduction of oxygen *via* a 4-electron step to form hydroxides in basic media (eq 1)

$$O_2 + 4e^- + 2H_2O \rightarrow 4OH^- \qquad (1)$$

The series pathway in basic media involves two successive 2-electron processes that proceed via hydrogen peroxide anion intermediate to give hydroxides (eqs 2 and 3). If the reaction terminates after the formation of the hydrogen peroxide anion intermediate, it is then termed a 2-electron pathway.

$$O_2 + 2e^- + H_2O \rightarrow O_2H^- + OH^- \qquad (2)$$

$$O_2H^- + 2e^- + H_2O \rightarrow 3OH^- \qquad (3)$$

The ORR pathway was investigated on PEDOT electrodes that were prepared using two different polymerization techniques, namely vapour-phase polymerization (VPP) and electropolymerization (EP). RRDE was used to detect the amount of hydrogen peroxide anion intermediate from eq. 2 that is formed during ORR on a PEDOT electrode. It was found that the ORR proceeds via a 2-electron pathway for EP-PEDOT, whereas on VPP-PEDOT it proceeds by either a 2-electron or 4-electron 'series' pathway, depending on the applied potential.

1. Winther-Jensen, B., et al., *High rates of oxygen reduction over a vapor phase-polymerized PEDOT electrode.* Science, 2008. **321**(5889): p. 671-674.

2. Ma, J., X. Wang, and X. Jiao, *Electrocatalytic reduction of oxygen on PEDOT-modified glassy carbon electrode.* International Journal of Electrochemical Science, 2012. **7**(2): p. 1556-1563

EXPERIMENTS IN STEAM FLUIDIZED BED DRYING OF LOW RANK COALS

Student: David Stokie **Display No.: 24**

Email Address: david.stokie@monash.edu

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: A/Prof.Sankar Bhattacharya

Phone: +61 3 9905 9623 **Email:** Sankar.bhattacharya@monash.edu

Project Summary:

A large proportion (76%) of Australia's power generation is based on coal power, with over 90% of Victoria's power reliant on brown coal combustion. Brown coal has high level of moisture (over 60%); this lowers efficiency of combustion and hence increases carbon dioxide emissions. An efficient way to remove coal moisture is through steam drying. This project investigates drying using steam fluidized beds, specifically obtaining the kinetics of drying. Currently, development of large scale steam fluidized bed drying is impeded by the lack of publically available information on the drying kinetics and resultant properties, which are required to assist scaling-up of the beds for commercial applications.

The project has following objectives:

- Use a range of fully-instrumented apparatus of varying scale to determinedrying kinetics - two thermo-gravimetric and one large scale continuous fluidized bed, purpose-designed,built and operated at Monash University
- Test the kinetic properties, to assessthe effects of bed mass, initial particle size, steam temperature, steam velocity and carrier gas on the drying time, drying rate and attrition of particles during drying.
- Assess the combustion and gasification reactivity of the coals dried under variety of conditions
- Use the generated information to develop a usable engineering model for steam drying of Victorian brown coal.

The experimental work is complemented by detail characterization of the samples using spectroscopic, calorimetric and electron microscopy techniques.

POWER GENERATION FROM SOLAR POND USING THERMOELECTRIC GENERATOR

Student: Baljit Singh Bhathal Singh **Display No.:** 25

Email Contact: s3350549@student.rmit.edu.au

Enrolled for: PhD **Status:** 2nd year

Tertiary Institution: RMIT University

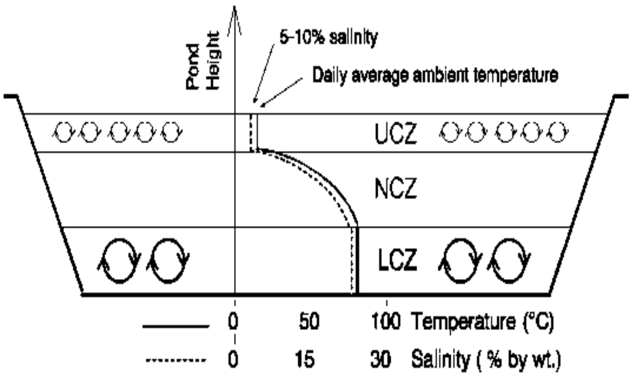
Department: School of Aerospace Mechanical and Manufacturing Engineering

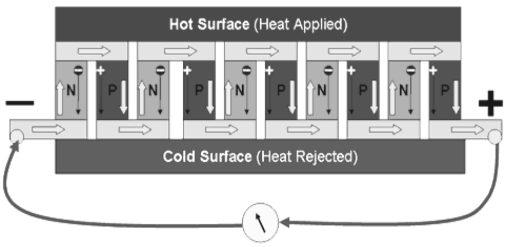
Supervisor: Prof. Aliakbar Akbarzadeh

Phone: +61 3 9925 6079 **e mail:** akbar@rmit.edu.au

Project Summary:

Aim of this research project is to develop a power generation system using low grade heat (600C - 900C) from the salinity gradient solar pond using thermoelectric generators. The Thermo-Electric Generators (TEG) system will be designed to be powered by the hot and cold water from the salinity gradient solar pond. The system will be capable of producing electricity even on cloudy days or at night as the salinity gradient solar pond has a large thermal storage.





Thermoelectric Generator (TEG)

Organic Rankine Cycle (ORC) engines currently dominate the power generation using low grade heat energy. ORC engines has many moving parts and move at very high speeds These systems often require lengthy maintenance and shut down service times. But, TEG based heat conversion system is much simpler compared to their ORC engine power plants. TEG based system do not require boiler, condenser, working fluid pump or turbine. It is purely a solid state device acting as compact passive heat exchanger. This build up makes TEG a reliable and low maintenance device. Additionally, the operation of the TEG system is quiet, due to the absence of any moving parts in them.

The proposed TEG systems with solar pond enable solar energy to be converted directly to Direct Current (DC) electricity using TEG. Solar pond allows the storage of heat energy even after sunset. This stored heat can be converted to electricity using TEG and eliminates the use of batteries for electricity storage. This makes TEG a new attraction for power generation from renewable energy where temperature gradients are available and capable of generating electricity 24 hours a day.

AN EXERGY ANALYSIS OF CO_2 COMPRESSION VERSUS LIQUEFACTION

Student: Jean Christophe Li Yuen Fong **Display No.: 26**

Email Address: chris.li@monash.edu

Enrolled for: PhD **Status**: 2nd year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: A/Professor Andrew Hoadley

Phone: +613 9905 4321 **E-mail:** Andrew.hoadley@monash.edu

Project Summary:

CO_2 capture processes need to be able to produce a high purity CO_2 stream with a minimum CO_2 purity of 95 vol%. When the purity is less than this, it is possible to improve the purity by separating any non condensable gases by liquefying the CO_2. In conventional multi-stage compression, the stream is compressed from 1 bar to 110 bar using a 4-stage compression system with inter-cooling using cooling water. The liquefaction process consists of three compression stages to 24 bar, liquefaction by cooling the stream to around -40°C and finally pumping the liquid to 110 bar.

There were four configurations of refrigeration cycle for the liquefaction processes that were considered in this study: four stage propane, four stage propylene, four stage propylene with sub cooling and a mixed refrigerant (ethane – propane) refrigeration cycle.

In order to analyse the processes, the minimum work required to operate the process and the exergy loss rate throughout the process was calculated. Exergy analysis determines both the thermodynamic losses of a system and the energy flow of a system by using a combination of the first law of thermodynamics (energy) and second law of thermodynamics (entropy).

After performing the simulations, the results of the calculations were tabulated in Table 1. As expected, the multi-stage compression had the minimum work required as well as the minimum exergy loss rate. This is due to the fact that the minimum theoretical amount of work required is higher for the liquefaction process due to the purification process. However, the minimum work required for the four-stage propylene with sub-cooling is only 6.3% more than the minimum work required for the compressor. In terms of exergy loss rate, mixed refrigerant was 9% higher than the compressor exergy loss rate.

Process	Min Work Required	Exergy Loss Rate
	MJ/ (t CO2 out)	
4 Stage Propane	521	660
4 Stage Propylene	521	656
4 Stage Propylene with Subcooling	500	575
Mixed Refrigerant	537	527
Compressor	470	468

Table 1. Minimum required and exergy loss rate of the different process configurations.

In conclusion, in terms of minimum work required and exergy loss rate, the multi-stage compressor provides the best case scenario. However considering the fact that the liquefaction process improves the purity of the feed stream and requires only 6% extra work required, the liquefaction process shows some potential for carbon capture processes such as membranes and adsorption technology, which cannot achieve high level of purity.

DC HYBRID REMOTE AREA POWER SYSTEM

Student: **Braden Kidd** **Display No.: 27**

Email address: bjkidd@student.unimelb.edu.au

Enrolled for: Master of Energy Systems **Status:** 1st year of a 2 year Masters

Tertiary Institution: University of Melbourne **Department:** Engineering

Supervisor: Assoc. Prof Michael Brear

Phone: 03 8344 6722 **Email:** mjbrear@unimelb.edu.au

Project Summary:

The aim of my Direct Current (DC) Hybrid Remote Area Power System is to provide the most efficient energy transfer between the source and the load, whilst retaining compatibility with Alternating Current (AC) infrastructure and appliances.

Renewable energy sources such as solar and wind, produce DC and this is fed into an energy storage device, usually batteries. The energy storage device stores the energy as DC and outputs DC. However, conventional infrastructure and appliances are designed to receive AC. This requires converting the DC to AC in order to power the respective loads.

That system was fine for powering AC appliances and equipment prior to the electronic age. However, not only computers and energy efficient lighting, but an ever increasing number of appliances and equipment have embedded electronic components which can only be powered by DC. The power losses that are incurred by multiple energy conversion processes between the source and the load are significant; only to then have the AC converted back to DC within the load itself.

In my DC Hybrid power system, the DC coming from the batteries is modified to be compatible with AC switches, power-points and most protective devices. As the DC Hybrid system only requires one processing stage, its power losses (1% - 2%), are significantly lower than the power losses in a conventional AC system (8% - 15%).

The design of the DC Hybrid system allows the output to supply a significantly larger surge current than an AC inverter. This makes the system more robust and less likely to fail than an AC inverter.

The relative simplicity of the DC Hybrid system means that it is also easier to scale. Increasing the power output does not lead to the major cost increases incurred when scaling up AC inverters.

My DC Hybrid Power System is simple, cost-effective, and robust. It is has high compatibility with AC infrastructure and appliances and can increase overall system efficiency in any situation where power has to be stored, or integrated with renewable energy sources. It would therefore have application not only for stand-alone power systems, but also for Uninterruptible Power Supplies (UPS).

In comparison to a conventional AC power system, my DC Hybrid system has the advantage of:

- Lower power conversion losses
- Higher surge current capacity
- Lower Cost to Scale
- Less complex

I have designed, built and tested a prototype system and I'm looking to set up a real-world test case.

EXPERIMENTAL INVESTIGATION OF CHEMICAL LOOPING COMBUSTION OF VICTORIAN BROWN COALS USING HEMATITE

Student: Sharmen Rajendran **Display No.: 28**

Email Address: sharmen.rajendran@monash.edu

Enrolled for: PhD **Status:** 1st year

Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: A/Prof Sankar Bhattacharya & Prof Klaus Hein

Phone: +61 3 9905 9623 **E mail:** sankar.bhattacharya@monash.edu

Project Summary:

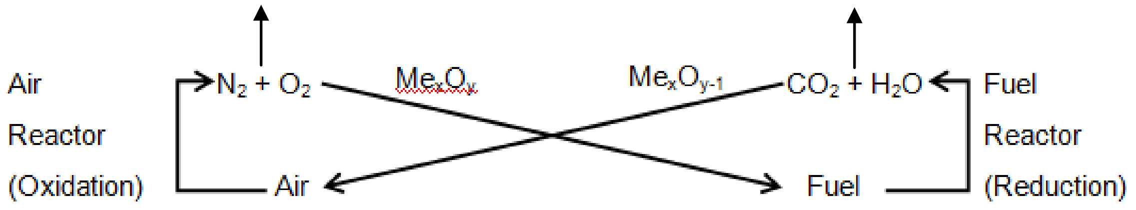


Figure 1: Representation of the interactions that occur in the chemical looping process

Process:

The oxygen carrier, typically a metal oxide, plays a key role in the chemical looping combustion process. The metal oxide in its fully oxidized state (Me_xO_y) transfers oxygen to the fuel reactor wherein combustion occurs with the fuel. The reduced metal oxide (Me_xO_{y-1}) is then transported to the air reactor and comes in contact with the air. The oxygen in the air acts as an oxidizing agent and returns the metal oxide to its fully oxidized state to begin a new reaction cycle.

Key issues for the success of this process are:

Oxygen carrier performance

Oxygen carrier and coal ash mineral interaction

Emission of trace elements and gaseous pollutants, and their effects on oxygen carrier.

Industrial Presence:

Global technology vendors (ALSTOM, Vattenfall) are front runners in the development of CLC

Our Work :

This is the first-ever study on CLC using Victorian brown coal complementing the work done by othes and technology vendors. Oxygen carriers of interest include metal oxides of transition elements (NiO, CuO, Fe_2O_3, Mn_2O_3) as well as inexpensive minerals (Ilmenite, iron ores)

The project involves systematic investigation of the issues highlighted above through a series of well controlled experiments, complemented with various instrument based analysis and modelling.

Experimental set-ups include steam injected TGA, 300W quartz reactor and a 4m tall $10kW_{th}$ fluidized bed reactor. Instrumental analyses include SEX-EDX, XRD, XPS, XRF, Mossbauer Spectroscopy, gas analysis and synchrotron based spectroscopy analysis.

Fe_2O_3 and iron ores are the best oxygen carriers resulting in high carbon conversion, > 90% CO_2 capture and no deterioration in their physical and chemical performance

<u>**TECHNO-ECONOMIC EVALUATION OF WATER SPLITTING TECHNOLOGIES TO PRODUCE HYDROGEN FOR AMMONIA PRODUCTION**</u>

Student: Sonal Thengane **Display No: 29**

Email Address: thenganesk@yahoo.com

Enrolled for: PhD **Status:** 2nd year

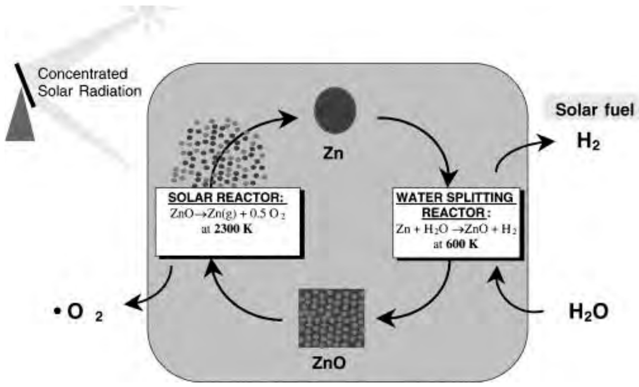
Tertiary Institution: Monash University **Department:** Chemical Engineering

Supervisor: Prof. Andrew Hoadley

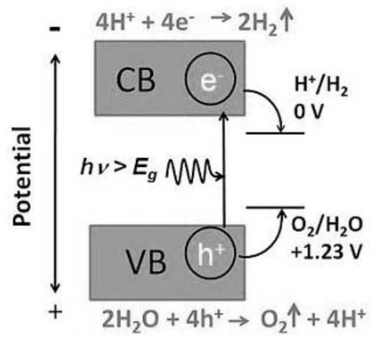
E mail: andrew.hoadley@monash.edu **Phone:** +61 3 9905 3421

Project Summary:

It is extremely important for the chemical industries to minimize their environmental emissions, and optimize the utilization of raw material and utilities. Hydrogen, a significant energy carrier, utility, and a feed component for the production of many widely used chemicals such as ammonia, is conventionally produced from natural gas consuming significant amounts of energy and with correspondingly high emissions. The objective of this research is to find the better options amongst all the available methods to produce hydrogen with the perspective of maximizing profit, and minimizing emissions. As there are many alternative technologies, the selection of the most appropriate technology can be viewed as a technology-ranking problem, where the rankings are arrived at through multi-criteria analysis like the Analytic Hierarchy Process (AHP). Sun and water being the inexhaustible renewable energy sources makes the water splitting reaction the most appealing pathway for sustainable hydrogen based energy economy. From the results of AHP it is found that water splitting by chemical looping and electrolysis are ranked most highly as alternative processes for producing hydrogen in near future. In the case of chemical looping, the high temperatures required can be attained through concentrated solar thermal energy whereas in the case of electrolysis the electricity can be obtained through solar photovoltaic, hydro, wind, etc., thus making both the approaches renewable. These processes can be employed individually or integrated with the conventional steam methane reforming process for efficient hydrogen production. Pinch analysis has been proved to be efficient in developing the best integrated process designs for both new plants and retrofits. The advanced renewable hydrogen production coupled with process integration has the potential to reduce costs and energy requirements along with the control of environmental emissions for the commercial production of chemicals such as ammonia.



Water splitting by chemical looping



Solar water splitting mechanism

ADVANCING OXY-FUEL COMBUSTION OF VICTORIAN BROWN COAL FOR LOW CARBON EMISSION

Student: Wirhan Prationo **Display No.: 30**

Email address: wirhan.prationo@monash.edu

Enrolled for: PhD **Status:** Commencing 2nd Year

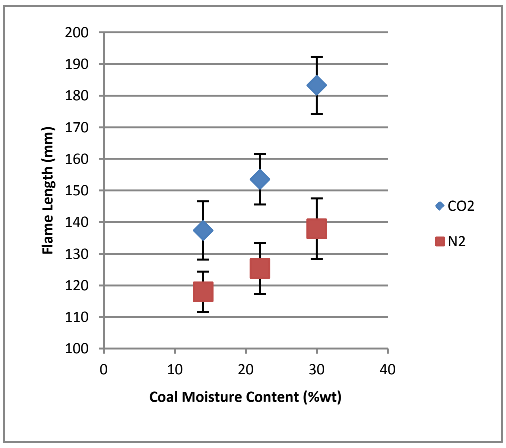
Tertiary Institution: Monash University **Department**: Chemical Engineering

Supervisor: Dr. Lian Zhang

Phone : +61 3 9905 2592 **Email:** lian.zhang@monash.edu

Project Summary:

Oxy-Fuel Combustion (OFC) has been deemed as one of the most feasible options in pulverized coal combustion for low carbon emission. It is a process of burning coal in the mixture of high purity oxygen and recirculated flue gas (RFG) to generate a capture ready CO_2-rich steam from power plant. The abundant moisture content (>70%wt) in Victorian brown coal is a critical factor affecting its combustion, either in conventional air or oxy-fuel combustion process. A partially dried coal after being heated will introduce moisture to the boiler which is expected to delay coal ignition and reduce flame temperature. In addition, upon the RFG in OFC, this steam entrained in RFG, if not fully condensed will be gradually accumulated in the boiler. It will affect heat flux in the boiler as steam possesses higher heat capacity than N_2. It will also affect the extent of carbon burnout compared to conventional air combustion. All this changes will affect the oxy-fuel burner design.



This aim of this project is to clarify how the moisture in coal and steam in RFG will affect the combustion behaviour of Victorian brown coal in the oxy-fuel mode. In this presentation, we report the ignition behaviour of both dried and wet Victorian brown coal, and compare the results between conventional air and oxy-fuel combustion. A laminar entrained flow facility with a flat flame burner was employed, which is coupled with in-situ optical diagnostic infrared pyrometer device and high speed camera. The high speed camera is capable of obtaining 1000 frames per second and helpful to clarify the coal combustion sequence down to microseconds scale. In addition, the char burning temperature is also recorded using infrared pyrometer.

The inherent moisture in the coal resulted in a longer flame length, as shown in the graph. This can be attributed to the delay in coal ignition which is due to extra time required for coal drying. Moreover, based on the high speed camera observation, the moisture in the coal particle is released smoothly and stayed preferentially on char surface rather than being released rapidly as a jet. The moisture released creates an additional boundary layer around the spherical particle which may affect the O_2 diffusion to the char, and even trigger char-steam gasification reaction.

The hypothesis has been verified based on infrared pyrometer observation. The wet coal char burning temperature appears to be lower, showing the preference of the steam to remain favourably on the char surface, which may even trigger the endothermic char-steam gasification reaction. In the case of oxy-fuel combustion, both char-CO_2 and char-steam gasification reaction may occur concurrently on the char surface, which further reduce char particle temperature. However, the extent of these reactions needs to be further clarified by means of kinetic modelling. Currently, the use of single film diffusion model is being investigated. In the future, the steam/O_2/CO_2 ratio in oxy-fuel combustion will be optimised to match the combustion in conventional air case. The location of oxygen and steam injection point will also be optimised and will give an overall overview of the burner design in oxy-fuel combustion.

AUSTRALIAN INSTITUTE *of* ENERGY

MELBOURNE BRANCH

Phone: 1800 629 945

Email: melb@aie.org.au

www.aie.org.au