AIE NATIONAL POSTGRADUATE STUDENT ENERGY AWARDS 2014

In conjunction with

All-Energy Exhibition & Conference

15th & 16th October 2014

Sponsored by:

and supported by:

THE AUSTRALIAN INSTITUTE *of* ENERGY

POSTGRADUATE STUDENT ENERGY AWARDS

15th October 2014

INTRODUCTION

The Australian Institute of Energy is pleased to stage another of its biennial Postgraduate Student Energy Awards, in conjunction with the All-Energy Exhibition and Conference. This year we are hosting the AIE National Student Awards and we encourage you to view the 25 student posters, including 9 representatives from 5 of our interstate Branches. We hope that you will be excited by what you see and hear and are confident that you will enjoy this always informative event.

The purpose of the 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, and compete for generous prizes from our sponsors while doing so. The students' objective is to communicate their particular research topic via a poster, a one page summary (found in this booklet) and personal discussions with delegates. They need to convey not only the nature of their project but also its relevance in the energy space. Some of the work presented has just commenced, while other projects are at the thesis write-up stage.

Please circulate around the poster displays and discuss the projects with the students. Your interest, helpful hints and constructive advice based on your experience will be welcomed by the students. We hope you take the opportunity to learn more about the leading-edge energy research currently being undertaken at our universities.

This Awards event would not happen without the generosity of our sponsors. 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: **Victorian Department of State Development & Business Innovation** *www.dsdbi.vic.gov.au*

AGL Energy - *www.agl.com.au*

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

Other Sponsors: **DNV GL -** *www.dnvgl.com*

CSIRO Energy Flagship *www.csiro.au/Organisation-Structure/Flagships/Energy-FlagshipI*

The competing students have put in a substantial effort, including many hours and creativity on their posters. The AIE and our sponsors wish to record our appreciation for their efforts and congratulation them on the high standard of their posters, summaries and explanations. We are sure their achievements at these Awards will be a significant step in their research activities and career development.

In addition to the Awards, the AIE offers all of the participating students who are not already members to join the AIE free of charge for the remainder of the financial year.

On behalf of the students, the AIE and our sponsors, we thank you for your interest and support.

David Allardice

David Allardice
AIE Student Awards Convenor

LIST OF STUDENT PROJECTS AND DISPLAYS

DISPLAY NO	STUDENT	TERTIARY INSTITUTE	DEPARTMENT	COURSE	YEAR	PROJECT TITLE	GROUP
1	Jinguk **KIM**	Melbourne	Chem & Biomol Eng	PhD	3rd	Development of CO_2 selective Ultra-thin film composite membranes via CAP nanotechnology for industrial use	A Carbon Reduction
2	Wuqiang **WU**	Melbourne	Chemistry	PhD	1st	3D branched anatase TiO_2 nanotree arrays thin films for high-efficiency perovskite solar cells	B Renewable Energy
3	Mahdi **SHAHNAZARI**	Murdoch	Eng & Info Tech	PhD	3rd	Effect of Political Cycles on power investment decisions: Expectations over the repeal and reinstatement of carbon policy mechanisms in Australia	C Future Energy
4	Anthony **DE GIROLAMO**	Monash	Chem Eng	PhD	2nd	Char-steam and Char-CO_2 gasification for Victorian brown coal char: Experiments and CFD modelling	A Carbon Reduction
5	James **BANAL**	Melbourne	Chemistry	PhD	2nd	Spectral Conversion in planar concentrators for efficient energy conversion	B Renewable Energy
6	Christopher **BARTLEY**	UCL (Adel)	Energy & Resources	MSc	2nd	Can you measure a social licence?	C Future Energy
7	Nouman **MIRZA**	Melbourne	Chem & Biomol Eng	PhD	2nd	Estimation of critical properties of deep eutectic solvents - potential low energy solvents for CO_2 absorption	A Carbon Reduction
8	Surya **KARTHIK MUKKAVILLI**	UNSW	PV Renewable Energy Eng	PhD	1st	Forecasting radiative effects of atmospheric aerosols: How bushfires and desert storms affect solar power integration	B Renewable Energy
9	Owen **SHARPE**	UCL (Adel)	Energy & Resources	MSc	2nd	An exploration of the constitution, and international regulatory barriers to an Australian state, participating as a fuel owner in a commercial, global nuclear fuel leasing program	C Future Energy
10	Joel **SCOFIELD**	Melbourne	Chem & Biomol Eng	PhD	3rd	High performance Thin-Film Composite Membranes based on amphiphilic block copolymers	A Carbon Reduction
11	Amir Bashirzadeh **TABRIZI**	Murdoch	Eng & Info Tech	PhD	3rd	Performance, reliability and safety of small wind turbines in the built environment	B Renewable Energy
12	Bartlomiej **KOLODZIEJCZYK**	Monash	Materials Eng	PhD	3rd	Conducting polymer alloys for photo-enhanced electro-catalytic oxygen reduction	C Future Energy

To find a poster, they are arranged in numerical sequence from the AIE booth (2823).

LIST OF STUDENT PROJECTS AND DISPLAYS (Cont.)

DISPLAY NO	STUDENT	TERTIARY INSTITUTE	DEPARTMENT	COURSE	YEAR	PROJECT TITLE	GROUP
13	Adam **RADY**	Monash	Chem Eng	PhD	Final	Evaluation of Victorian brown coal as a fuel for Direct Carbon Fuel Cells	A Carbon Reduction
14	Benjamin **YAP**	Melbourne	Chem & Biomol Eng	PhD	3rd	Algal biodiesel - The role of cell disruption in lipid recovery	B Renewable Energy
15	Pouya Ghadimi **KARAHRODI**	UNSW	Mech & Manufact. Eng	PhD	3rd	Energy monitoring & smart grid application in manufacturing	C Future Energy
16	David **DANACI**	Melbourne	Chem & Biomol Eng	PhD	3rd	Evaluation of ZIF's -8, -14 & -71 for the upgrading of sour natural gas	A Carbon Reduction
17	Suzanne **MARSH**	Queensland	International.. Energy Center	M Energy Studies	1st	Rarotonga's renewable energy opportunities	B Renewable Energy
18	Ehsan **MALEKIMOSTAGHM**	Curtin	Petroleum Eng	PhD	1st	Determination of cementation exponent (m) in gas shale reservoirs	C Future Energy
19	Hiep Thuan **LU**	Melbourne	Chem & Biomol Eng	PhD	1st	Impact of water on the performance of cellulose acetate membrane for CO_2 separation	A Carbon Reduction
20	Eshan **AHUJA**	ANU	Energy Change Inst	M Energy Change	2nd	Techno-economic pre-assessment of waste-to-fuel processing in ACT	B Renewable Energy
21	Lu **XIA**	Melbourne	Elec & Electronic Eng	PhD	2nd	Enernet of things: Demand side management for smart grid using game theory and big data analytics	C Future Energy
22	Wirhan **PRATIONO**	Monash	Chem Eng	PhD	3rd	The role of inherent moisture on brown coal ignition and combustion in Oxy-fuel Combustion	A Carbon Reduction
23	Simon **TAKOURIDIS**	Melbourne	Chem & Biomol Eng	PhD	3rd	An elite variety of Algae for feed and biofuel	B Renewable Energy
24	Renée **WEBSTER**	Monash	Chemistry	PhD	2nd	Investigating the oxidation of synthetic jet fuels with two-dimensional gas chromatography	C Future Energy
25	Yue (Frank) **WU**	Melbourne	Chem & Biomol Eng	PhD	1st	Rate based modelling of Potassium Carbonate (K_2CO_3) precipitating absorption columns in carbon capture	A Carbon Reduction

To find a poster, they are arranged in numerical sequence, from the AIE booth (2823).

THE AWARDS AND CATEGORIES

The objective of this event is to give the 25 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 3 groups with approximately equal numbers of projects and some common elements within a group, to give the students an equitable chance of winning an award. The divisions are somewhat arbitrary but we have to work with the project topics which have been entered. The broad groupings are:

- **Category A** - '**Carbon Reduction'**
- **Category B - 'Renewable Energy**'
- **Category C - 'Future Energy'**.

Nine awards will be presented following an assessment of the projects by a panel of judges. The winners will be announced and awarded their prizes at the end of the pre-lunch Energy Storage session at the All-Energy Conference on Thursday 16th October (in Room 216 from 12:15 pm).

The Awards and their sponsors are listed in the following table.

Award		Sponsor
ALL COMPETITORS		(Nos 1 to 25)
Best Project	$1,000	**Victorian Dept of State Development & Business Innovation (DSDBI)**
Highly Commended	$800	**AGL Energy**
Group A - CARBON REDUCTION		(Nos 1,4,7,10,13,16,19,22 & 25)
Best Project	$750	**Brown Coal Innovation Australia**
Highly Commended	$500	**Brown Coal Innovation Australia**
Group B - RENEWABLE ENERGY		(Nos 2,5,8,11,14,17,20 & 23)
Best Project -	$750	**DNV GL**
Highly Commended	$500	**CSIRO Energy Flagship**
Group C - FUTURE ENERGY		(Nos 3,6,9,12,15,18,21 v& 24)
Best Project	$750	**AGL Energy**
Highly Commended	$500	**DSDBI**
ENCOURAGEMENT	$500	**AIE & All-Energy**

STUDENT SUMMARIES & POSTERS

The individual project summary sheets prepared by the students are reproduced in numerical sequence in the following pages with alternating summaries from Groups A, B, and C.

The project posters will be on display in the same sequence in the Exhibition Hall, (along the rear wall), adjacent to the AIE booth, No. 2823.

DEVELOPMENT OF CO_2 SELECTIVE ULTRA-THIN FILM COMPOSITE MEMBRANES VIA CAP NANOTECHNOLOGY FOR INDUSTRIAL USE

STUDENT: JINGUK KIM **DISPLAY NO. 1**

Email: jkim@student.unimelb.edu.au

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

University: The University of Melbourne

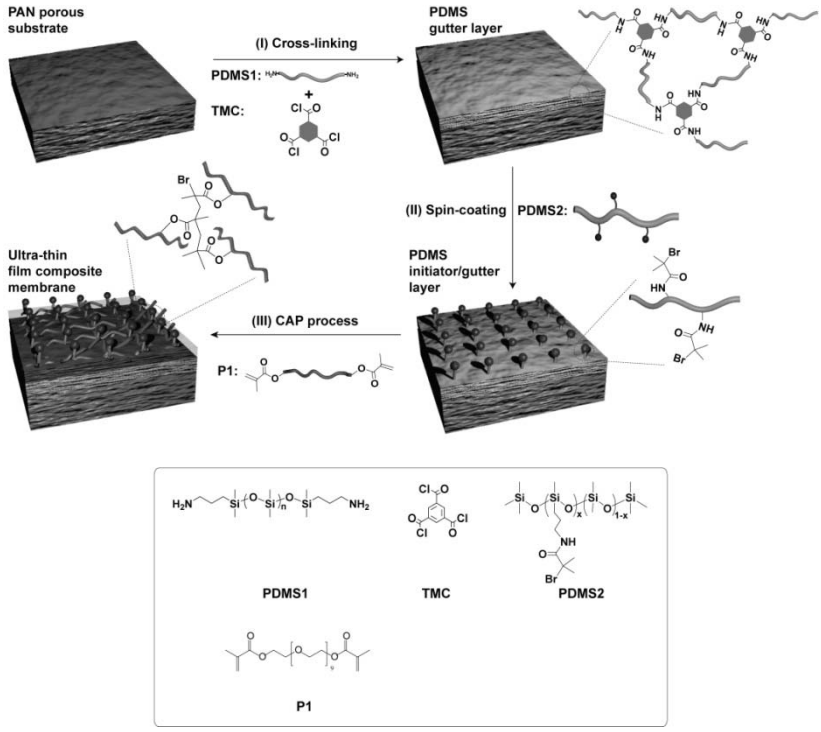
Department: Chemical and Biomolecular Engineering

Supervisor: Prof. Greg Qiao and Prof. Sandra Kentish **E mail:**… gregghq@unimelb.edu.au

PROJECT SUMMARY:

Many efforts have been made to reduce the cost of carbon dioxide capture. The overall cost of Carbon Capture and Storage is dominated by the CO_2 capture step due to the low partial pressure of CO_2 (13 v/v%) and the large volume of gas (11,000 ton CO_2/day) released from a typical coal fired power plant. To cope with the massive flux of flue gas, new membrane materials have been investigated with impressively high CO_2 permeability and CO_2/N_2 selectivity reaching above the trade-off trend, suggested by Robeson. However, there is a gap to be filled between industrial demand and research outcomes. It is proposed by Merkel *et. al.* that a CO_2 permeance over 1000 GPU and a CO_2/N_2 selectivity over 20 is required for the CO_2 separation membranes to satisfy cost-effective CO_2 capture in industrial practice. Otherwise, a large membrane surface or highly compressed feed gases are required to achieve the necessary CO_2 flowrates.

This project focuses on the preparation of ultra-thin film composite (UTFC) membranes consisting of an ultra-thin selective film (< 100 nm) and a highly permeable gutter layer deposited onto a porous substrate. The selective layer is fabricated by a recently developed nanotechnology approach, namely the continuous assembly of polymers (CAP). The new approach allows the fabrication of surface-confined and cross-linked selective layers with the thickness controlled at the nano-scale. Furthermore, hybrid organic-inorganic nanoparticles are incorporated into the CAP selective layer for further improvement of CO_2/N_2 selectivity. Consequently, we can improve the CO_2 permeance by the reduction of the CAP layer thickness and achieve impressive CO_2/N_2 selectivity, leading to economical CO_2 capture via a membrane process with high gas productivity.



Scheme 1 The fabrication of ultra-thin film composite membrane via the continuous assembly of polymer (CAP) process.

3D BRANCHED ANATASE TiO_2 NANOTREE ARRAYS THIN FILMS FOR HIGH-EFFICIENCY PEROVSKITE SOLAR CELLS

STUDENT: WUQIANG WU **DISPLAY NO. 2**

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

University: The University of Melbourne

Department: School of Chemistry

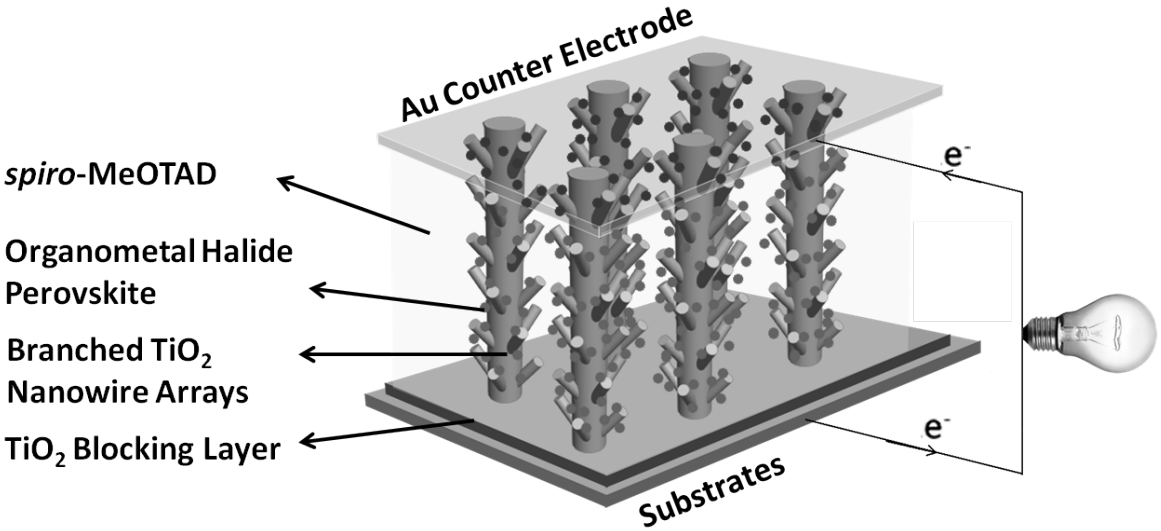
Supervisor: Assoc. Prof. Rachel A. Caruso **E mail:** rcaruso@unimelb.edu.au

PROJECT SUMMARY:

Solar energy is regarded as a promising energy source that has great potential to cater for the increasing global energy demand without adding appreciably to the greenhouse effect. In particular, solar cells that directly convert solar light into electricity have attracted considerable interest in both scientific and technological fields.

Over the past two decades, tremendous effort has been made to construct smart designs of nanostructured materials and photovoltaic devices. Of particular interest is the semiconducting nanostructured arrays including nanorods, nanowires and nanotubes, which are capable of providing a direct electron transfer pathway and effectively suppressing recombination of photon-generated charges, thus improving the charge collection efficiency when applied in the solar cells.

The aim of this project is to synthesize thin films of branched anatase TiO_2 nanowire arrays on transparent conducting oxide substrates for the emerging state-of-the-art perovskite solar cells with outstanding solar-to-electric power conversion efficiency. The proposed 3D branched TiO_2 nanowires (seen in *Scheme 1*) could offer a number of synergic advantages, including a highly porous network for effective sensitizer anchoring, excellent electron transfer and long electron lifetime for boosting the charge collection efficiency, improved light adsorption (prolonged optical path, increased light trapping and superior multi-scattering capability) for enhancing light harvesting.



Scheme 1. *Sketch of perovskite photovoltaic device based on 3D branched TiO_2 nanowire arrays.*

The goal of the current project is to synthesize a series of novel branched TiO_2 nanowire arrays with tunable morphologies and properties (crystallinity, porosity, branch density and placement, size and length) and to employ them as efficient electron collection photoelectrodes, thus making high-performance perovskite solar cells.

THE EFFECT OF POLITICAL CYCLES ON POWER INVESTMENT DECISIONS: EXPECTATIONS OVER THE REPEAL AND REINSTATEMENT OF CARBON POLICY MECHANISMS IN AUSTRALIA

STUDENT: MAHDI SHAHNAZARI **DISPLAY NO. 3**

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University: Murdoch University

Department: School of Engineering and Information Technology

Supervisor: Dr. Jonathan Whale, Dr. Bryan Maybee, Mr Adam McHugh

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PROJECT SUMMARY:

Political uncertainty over global greenhouse gas (GHG) mitigation policy is likely to defer investment in cleaner technologies. It may also incentivise short-lived, high-cost interim investments while businesses wait for the uncertainty to subside. The range of possible policy responses to the issue has created uncertainty over the future of national mitigation pathways. Given that the electricity sector, globally, is a major emitter of GHGs, this represents a systematic risk to investment in electricity generation assets.

For more than a decade, emission-trading mechanisms have been on top of climate policy agenda in Australia, finally enacted in 2011. Although the *Clean Energy Act 2011* began with a fixed carbon tax period followed by emission trading due to start from 2015, the efficacy of policy was eroded by political uncertainty related to the possibility of the policy's repeal, due to a lack of bipartisan support. The carbon tax was repealed in mid-2014, however, a reinstatement is a possibility considering the effect of the electoral cycles in Australia and more stringent global mitigation efforts.

This study develops a decision framework to investigate one potential business response to carbon pricing at a private investor's disposal. It investigates the optimal timing for investment in the conversion of a coal plant to a combined cycle gas turbine plant using the American–style option valuation method. We employ a real options analysis framework informed by a survey of experts conducted in Australia – used as a proxy to model the degree of the uncertainty. Political uncertainty is addressed bi–modally in terms of: (1) uncertainty over the repeal of the carbon pricing policy, and (2) if it is repealed, uncertainty over the reinstatement of the policy, to represent the effect of electoral cycles and the possibility of more stringent future global mitigation efforts.

The results of the analysis show that although political uncertainty with respect to GHG mitigation policy may delay investment in the conversion of the coal plant, expectations over the reinstatement of the carbon pricing reduces the amount of option premium to defer the conversion decision. The findings also suggest that signalling high carbon prices can mitigate the effect of political uncertainty. A quantitative decision metric was introduced to provide investors with a decision criterion that can be used to recommend the optimal investment timing.

Two recommendations to policy makers arise from the research. The first is that those who are serious about meeting carbon policy objectives should try to create a more stable political environment, as controversy over the survival of carbon pricing legislation may be detrimental to a desired investment in cleaner technologies. The second is that setting a higher carbon price, and commitment over green political pledges may dampen the effects of political uncertainty and improve the business case for earlier converting to lower emission systems, should a more stable environment not be found.

Two papers from this research have been published in the latest editions of Applied Energy:

M. ShahNazari, A. McHugh, B. Maybee, J. Whale, The effect of political cycles on power investment decisions: Expectations over the repeal and reinstatement of carbon policy mechanisms in Australia, Applied Energy, Volume 130, 1 October 2014, Pages 157-165, http://dx.doi.org/10.1016/j.apenergy.2014.05.040.

M. ShahNazari, A. McHugh, B. Maybee, J. Whale, Evaluation of power investment decisions under uncertain carbon policy: A case study for converting coal fired steam turbine to combined cycle gas turbine plants in Australia, Applied Energy, Volume 118, 1 April 2014, Pages 271-279, http://dx.doi.org/10.1016/j.apenergy.2013.12.050.

CHAR-STEAM AND CHAR-CO_2 GASIFICATION FOR VICTORIAN BROWN COAL CHAR: EXPERIMENTS AND CFD MODELLING

STUDENT: ANTHONY DE GIROLAMO **DISPLAY NO. 4**

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

University: Monash University

Department: Chemical Engineering

Supervisor: Dr Lian Zhang **E mail:** lian.zhang@monash.edu

PROJECT SUMMARY:

This study aims to clarify the extent to which char gasification reactions contribute in the overall char conversion in low rank coal. At lower temperatures, many studies on bituminous coal have found gasification reactions to be negligible on the overall char conversion. This study finds that the reaction rates of gasification reactions may be up to 40 times higher for brown coal than bituminous coal.

Although the kinetic rate of reaction may be much smaller for the char-CO_2 reaction compared to char oxidation, the elevated levels of CO_2 in oxy-fuel combustion and may affect the conversion rate. In wet flue gas recycle, a large amount of steam may accumulate, especially for coals with higher moisture content such as Victorian brown coal. This will convert char in the form of the char-H_2O gasification reaction. As temperature increases the rate of the char-CO_2 and char-H_2O reactions will increase at a higher rate compared to char oxidation due to the larger activation energies.

The degree of char conversion and rate of char reactions which affect particle temperature as well as the surrounding gas environment could influence the rate at which alkali metals such as sodium are vaporized from the char particle. Vaporisation of metals is influenced by the reducing atmosphere where metal oxides will undergo reduction through carbon monoxide to form the more volatile elemental metal and carbon dioxide as a product. In an oxy-fuel environment, a large amount of carbon dioxide will be present in the bulk gas theoretically resulting in a lower vaporisation; however, a carbon dioxide molecule reacting with the char will generate two carbon monoxide molecules. Additionally carbon monoxide is a product of the steam gasification reaction.

SPECTRAL CONVERSION IN PLANAR CONCENTRATORS FOR EFFICIENT ENERGY CONVERSION

STUDENT: JAMES BANAL **DISPLAY NO. 5**

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

University: The University of Melbourne

Department: `School of Chemistry

Supervisor: Prof Kenneth Ghiggino/Dr Wallace W.H. Wong **E mail:** ghiggino@unimelb.edu.au

PROJECT SUMMARY:

Luminescent solar concentrators (LSCs) based on fluorescent dyes have been proposed as a promising technology towards reducing the amount of photovoltaic material required for solar harvesting. An LSC is a simple light-concentrating device in contrast to parabolic concentrators. A typical configuration is a flat sheet of plastic/glass (a waveguide) containing light absorbing and emitting dyes. The photoluminescence from the dyes is then trapped in the waveguide and concentrated at the edges by total internal reflection (Figure 1). LSCs have the tremendous potential to further decrease the cost of silicon photovoltaics[1], enable the large-scale use of concentration-enhanced photovoltaics such as multijunction solar cells,[2] and enhance the performance of other solar harvesting technologies.[3] However, the performance of LSCs has been limited by the properties of the emitters used that reduce the light concentration efficiency. This project is focused on reducing the limitations of existing LSCs by developing new light emitters with improved performance. Several novel fluorescent materials have been made based on twisted molecular structures that reduce the parasitic light losses of existing LSC dyes.[4,5] Evaluation of these materials in LSCs show they have the potential to improve the technology so it can be cost competitive for large-scale applications such as solar harvesting windows.

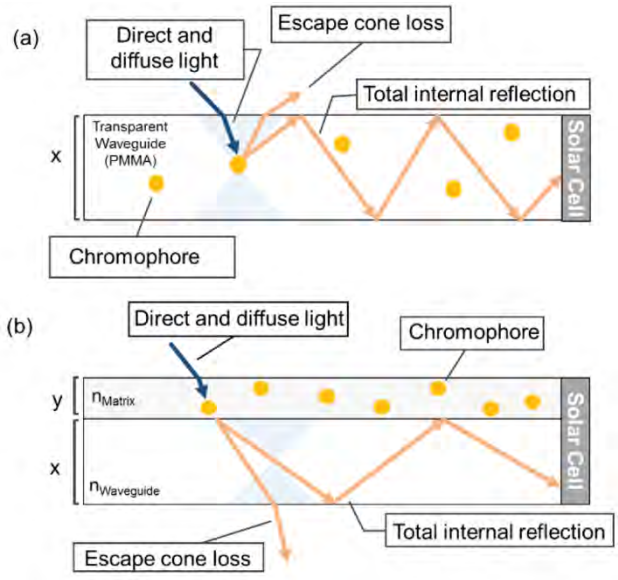

Figure 1. Configurations of luminescent solar concentrators (a) fluorescent dyes doped in a plastic waveguide and (b) dyes dispersed in a polymer film on the waveguide surface. n_{Matrix} is the refractive index of the host matrix; $n_{Waveguide}$ is the refractive index of the waveguide; x and y are the thicknesses of the waveguide and the matrix, respectively.

1 Yoon, J. *et al.* Flexible concentrator photovoltaics based on microscale silicon solar cells embedded in luminescent waveguides. *Nature Commun.* **2**, 343, (2011).

2 Sheng, X. *et al.* Printing-based assembly of quadruple-junction four-terminal microscale solar cells and their use in high-efficiency modules. *Nature Mater.* **13**, 593-598, (2014).

3 Wondraczek, L. *et al.* Solar spectral conversion for improving the photosynthetic activity in algae reactors. *Nature Commun.* **4**, (2013).

4 Banal, J. L., Ghiggino, K. P. & Wong, W. W. H. Next Generation Solar Concentrator. Australia patent 2013904551 (2013).

5 Banal, J. L., White, J. M., Ghiggino, K. P. & Wong, W. W. H. Concentrating aggregation-induced fluorescence in planar waveguides: a proof-of-principle. *Sci. Rep.* **4**, 4635, (2014).

CAN YOU MEASURE A SOCIAL LICENCE?

STUDENT: CHRISTOPHER BARTLEY **DISPLAY NO. 6**

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Department: School of Energy & Resources

Supervisor: Dr. Craig Styan **E mail:** c.styan@ucl.ac.uk

PROJECT SUMMARY:

It is now widely accepted that companies require a 'social licence to operate' – especially in the energy and resources sector. This is often defined as "the ongoing approval or broad public acceptance of a project by its stakeholders", yet despite a willingness to engage, many companies face difficulty in developing concrete objectives and corporate strategies to meet this goal. A key problem lies in the failure of capturing and presenting the data collected in social surveys in a way that can be used intuitively by senior decision makers.

A common approach is to survey the attitudes and perceptions of local stakeholders – but, typically, results are presented as a series of indeterminable bar charts showing, for example, that the overall level of support has dropped by 3%, or that 72% of the community now think that the project creates jobs. While this approach provides valuable preliminary descriptive information about each individual variable, it offers limited value in understanding the drivers of community acceptance, which are complex, interlinked, and often missed amongst the plethora of reported measures. Improvements are needed in both the measurement of a social licence and the way that survey data is analysed and presented to mangers. A 14-item social licence survey has been developed by CSIRO and tested over three years at a multi-billion dollar gas development in Queensland. The purpose of this research was to present and interpret this data using a mathematical visualisation technique called multidimensional scaling (MDS).

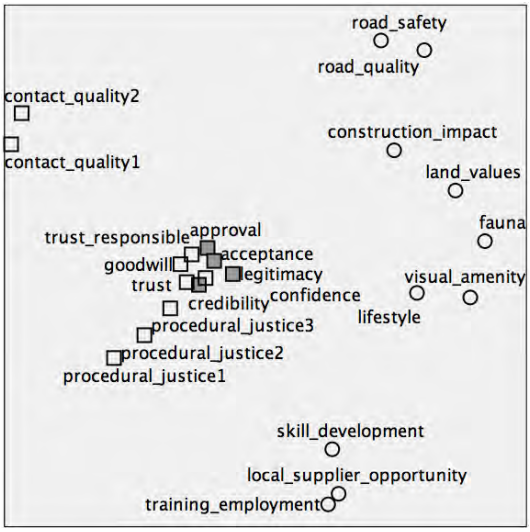

Figure 1: The importance of different factors on the company's social licence to operate

Multidimensional scaling was used to visually explore the dataset and identify hidden patterns and relationships among factors. The key benefit is the ability to explore multiple variables simultaneously, without simplification of the underlying data. The graphical output is simple to understand and does not require in-depth statistical knowledge; it is commonly used by psychologists and market researchers, however this study is its first application in the social licence domain.

The data was analysed in two ways. The first analysis showed the relationship between each survey variable, and their importance to the company's social licence. In Figure 1, each point is a survey item, and the distance between points represents their correlation. The closer the points are to each other, the higher their correlations are.

It shows that the key factors of Trust and Procedural Justice (squares) were closer to the acceptance cluster (shaded squares), than any of the impacts experienced by the community. This indicates that trust and procedural justice are more closely linked to acceptance of the project than any other factors. The second analysis represented each of the 214 respondents as points on the MDS map. This was used to identify people with similar response profiles (e.g. those strongly opposed) and to analyse their group membership. It was also used to picture the response patterns of different demographic groups, and to visualise trends in their responses over time.

The results demonstrate the ability of MDS to visually present complex structures of survey results. The output is clear and concise, and would be particularly suited to digital display such as on a corporate reporting dashboard. The graphical approach makes social survey data accessible to engineers and managers. This, in turn, could lead to better management of social licence issues in the energy industry, and create better outcomes for both the company and community.

ESTIMATION OF CRITICAL PROPERTIES OF DEEP EUTECTIC SOLVENTS – POTENTIAL LOW ENERGY SOLVENTS FOR CO_2 ABSORPTION

STUDENT: NOUMAN RAFIQUE MIRZA **DISPLAY NO. 7**

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

University: The University of Melbourne

Department: Department of Chemical & Biomolecular Engineering

Supervisors: Prof. Geoffrey W. Stevens, Prof. Sandra Kentish, Dr. Nathan J. Nicholas

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PROJECT SUMMARY:

A deep eutectic solvent (DES) is a combination of an organic salt and a hydrogen bond donor, which when mixed in a certain molar ratio and heated mildly, result into a clear liquid. The liquid has a significantly lower freezing temperature than the precursors' and is called a deep eutectic solvent. DESs can often be manufactured from easily available, biodegradable, sustainable, non-flammable and non-toxic precursors with very high purity (even in laboratory). These solvents can absorb CO_2 (SO_2 as well) from flue gases being emitted from power plants. Besides being very cheap, these have negligible vapour pressure, resulting in negligible solvent loss. These are also non-aqueous solvents. Water has high heat capacity. Absence of water means that these solvents have the potential to reduce overall CO_2 capture energy by 49%.

In order to develop chemical processes (e.g. CO_2 capture process) based upon DESs, thermodynamic modelling of these solvents needs to be understood. To model the thermodynamics of these solvents, information about their critical properties is needed. Critical properties of these solvents cannot be determined experimentally as at high temperatures and pressures, these tend to thermally decompose. Therefore, empirical, theoretical models have to be utilized to estimate the critical properties of these solvents. In the present study, a combination of modified Lydersen-Joback-Reid method and Lee Kesler's mixing rules has been applied to estimate the critical properties of 39 different DESs.

To test the accuracy of estimation, densities of these DESs are determined from the estimated critical properties and then compared with experimental values. Absolute deviations (AD) for estimated densities ranging from 0.00% to 17.36% were observed, indicating a good estimation of critical properties. An overall absolute deviation of 4.9% is observed for the whole range of studied DESs. Absolute deviations for DESs consisting of aliphatic precursors ranged from 0.00% to 9.50% whereas for DESs consisting of at least one aromatic precursor these ranged from 5.79% to 17.36%. The method was also found to accurately take into account the variation in molar ratios of precursors and the variation in density due to a temperature change and give satisfactory results. Presence of aromatics in DESs resulted in less accurate prediction of critical properties and the loss in accuracy increased if in a certain type of DES, the mass percentage of hydrogen bond donor (HBD) was increased (by changing the molar ratio of precursors).

FORECASTING RADIATIVE EFFECTS OF ATMOSPHERIC AEROSOLS — HOW BUSHFIRES AND DESERT STORMS AFFECT SOLAR POWER INTEGRATION

STUDENT: SURYA KARTHIK MUKKAVILLI **DISPLAY NO. 8**

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

University: University of New South Wales

Department: School of Photovoltaic & Renewable Energy Engineering

Supervisor: Dr. Merlinde Jacqueline Kay **E mail:** m.kay@unsw.edu.au

PROJECT SUMMARY:

Increasing environmental and economic risk associated with conventional fossil fuels is resulting in greater worldwide demand for renewable energy systems. Solar energy is currently one of the fastest growing mixes of energy generation worldwide. However, the power output from solar energy systems depend on meteorological parameters and entities such as temperature, precipitation, clouds and atmospheric aerosols.

Atmospheric aerosols stem from various human emissions and natural sources such as desert storms, bushfires, sea salt and burning fossil fuels. Under clear sky conditions where solar power plants are most viable economically, aerosols directly affect the shortwave, visible direct solar irradiance component. These aerosol nanoparticles have a significant influence on air quality as smog over cities; and change the climate and weather through precipitation and cloud microphysics as cloud condensation nuclei. In particular, a large source of uncertainty in climate and weather prediction models is due to the radiative effects, morphology and dynamics of aerosols. Since aerosols scatter, absorb and reflect radiation, they affect surface solar radiation measurements.

Concentrated solar power (CSP) plants bid into the national electricity market to capture peak prices, schedule thermal energy storage and dispatch electricity based on the reliability of direct solar irradiance forecasts. Predicting solar radiative effects from frequent aerosol events such as desert dust storms and biomass smoke plumes can contribute to economic benefits for these CSP plant operators in Australia. Investigating radiative effects, spatial and temporal variability of atmospheric aerosols is of significance to stability and economics of future electric grids where solar energy will play a critical role. Therefore, developments in solar forecasts from improved aerosol modelling are intrinsically linked to large-scale integration of solar energy systems into the national grid.

This project is a highly multi-disciplinary effort that bridges gaps across different scientific fields using state of the art radiative transfer, numerical weather prediction (NWP) and computational techniques on supercomputers to forecast the radiative effects of aerosol nanoparticles for solar power plants. Satellite data for solar irradiance is validated with ground based measurements from Bureau of Meteorology and incorporated into National Centre for Atmospheric Research's (NCAR) widely used mesoscale NWP Weather Research & Forecast (WRF) model.

The proposed methodology is developed as part of a Commonwealth Scientific & Industrial Research Organisation (CSIRO) and University of New South Wales (UNSW) collaboration on the Australian Renewable Energy Agency (ARENA) funded Australian Solar Energy Forecasting System (ASEFS) project.

AN EXPLORATION OF THE CONSTITUTION, AND INTERNATIONAL REGULATORY BARRIERS TO AN AUSTRALIAN STATE, PARTICIPATING AS A FUEL OWNER IN A COMMERCIAL, GLOBAL NUCLEAR FUEL LEASING PROGRAM

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RESEARCH SUMMARY:

Australia is a major player in the international uranium market, holding around 29% of the world's low cost reserves of the mineral and being the third largest nuclear fuel supplier globally. However, in economic terms uranium is dwarfed by iron ore, black coal and copper. Whilst nuclear energy holds the potential to provide cheap, reliable, carbon-free energy, it is subject to radiation concerns as well fears that it could be proliferated for weapons programs. Spent nuclear fuel remains a continuing restraint on the global expansion of nuclear energy, whereby no single government has succeeded in opening a long-term waste repository.

Increased interest in nuclear energy has given rise to the notion of a *"nuclear renaissance"* with the *International Atomic Energy Agency* ('IAEA') reporting that 60 countries non nuclear power nations are considering nuclear power, out of which 10-25 are expected to bring nuclear power plants on line by 2030. The majority of such nations are identified as emerging economies, which are anticipated to account for more than 90% of net energy demand growth to 2035. Many developing nations within Australia's immediate region have either begun or signalled their intent to produce nuclear energy, including China, India, Malaysia, Thailand and Vietnam. As a major nuclear fuel supplier, Australia therefore has a direct interest in ensuring the effectiveness of global nuclear governance to ensure that energy use in its region is safe and secure.

The concept of **'Nuclear Fuel Leasing'** could have positive implications for Australia's role in the nuclear fuel cycle. Nuclear fuel leasing is a 'whole of life' approach to the nuclear fuel cycle which involves 'fuel supplier nations' (such as Australia) exporting uranium to 'user nations' and then receiving back spent nuclear fuel for storage and/or disposal. Some proposed benefits of nuclear fuel leasing include:

- *Enhancing the international regime of non-proliferation and safeguards;*
- *Financial benefits as an added value to Australian uranium production;*
- *Improvement of existing nuclear requirements and possible future establishment of a nuclear power industry in Australia; and*
- *Further political, ethical and environmental reasons why Australia should take the lead in fuel leasing.*

However, previous research on nuclear fuel leasing has focussed almost exclusively on socio-economic aspects to the concept. As such, this dissertation purports to advance our understanding of the legal and regulatory barriers to an Australian Nuclear Fuel Leasing program. This study has three Research Questions:

1. What is the current Australian legal and regulatory framework relevant to an Australian nuclear fuel leasing scheme?
2. What are the barriers to an Australian nuclear fuel leasing scheme given the existing legal and regulatory framework?
3. What will be required to overcome the legal and regulatory barriers to Australian nuclear fuel leasing?

Ultimately, this Masters dissertation aims to develop a legal and regulatory model for the establishment of a commercial Australian global Nuclear Fuel Leasing program. See more at: http://youtu.be/nPxdzj4i4mE

HIGH PERFORMANCE THIN-FILM COMPOSITE MEMBRANES BASED ON AMPHIPHILIC BLOCK COPOLYMERS

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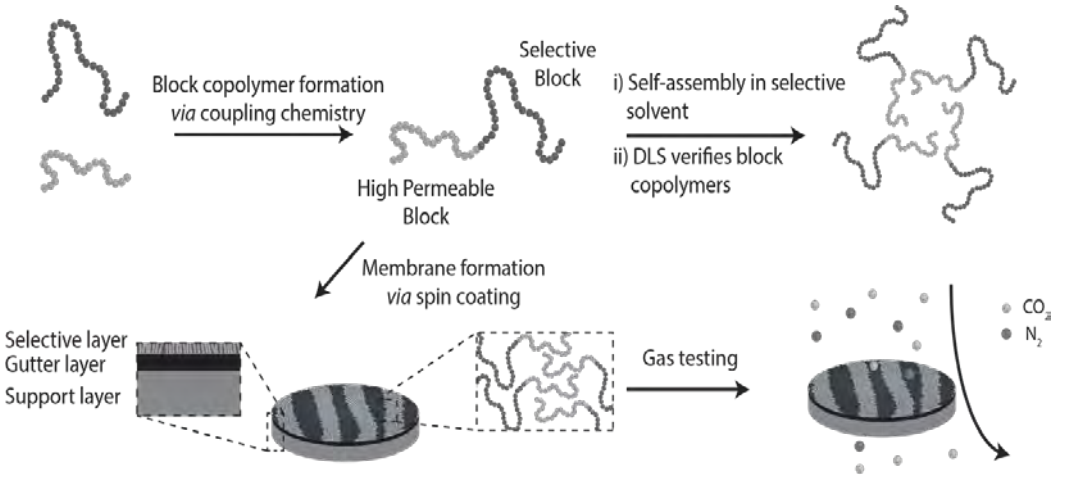
PROJECT SUMMARY:

Polymeric membranes are one of the proposed technologies for the removal of carbon dioxide (CO_2) from coal fired power stations as a method for reducing the human impact on climate change. Gas separation membrane have several advantages over conventional amine based solvent adsorption processes, including lower waste products and lower separation costs [1]. The thin-film composite membranes containing block copolymers, developed in this project aim to increase the efficiency of CO_2 gas separation by increasing the flux of gas able to be processed, whilst maintaining the selectivity towards CO_2 over other flue gases.

Block copolymers have received significant attention due to their ability to combine the desirable physical properties of individual segments. In addition to self-assembly, the synthesis of precise block copolymers enables a combination of polymer segments which would normally phase separate.

Poly(ethylene glycol) (PEG) has been reported to have high selectivity towards CO_2 over N_2, while hydrophobic poly(dimethylsiloxane) (PDMS) has been reported to have a high CO_2 flux and is commonly used in the membrane industry [2, 3]. The combination of these materials through the formation of block copolymers enables the incorporation of PDMS into membranes which maintain high selectivity due to the PEG component, while increasing the flux due to the PDMS component.

In this project block copolymers containing hydrophilic PEG segments and hydrophobic PDMS segments were synthesised in a range of molecular weights and component fractions. The structures of these polymers were confirmed using a range of analytical techniques. The combination of these two moeities allowed for the stabilization of the hydrophobic PDMS component in selective polar polymers such as polyether oxides. Thin-film composite (TFC) membranes were formed *via* spin-coating, with a thin selective layer which comprised of the block copolymer additive mixed within a commercial PEBAX® matrix. Gas permeation results verified a doubling in the flux of gas through the membrane as a result of the incorporation of block copolymers, whilst maintaining gas selectivity.



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PERFORMANCE, RELIABILITY AND SAFETY OF SMALL WIND TURBINES IN THE BUILT ENVIRONMENT

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PROJECT SUMMARY:

Wind turbines have traditionally been used in rural areas in open terrain that is exposed to the wind. There has, however, been an increasing trend towards the installation of wind turbines in non-open terrain, such as in urban areas, above forests and in mountainous areas. The drivers for the change in turbine location include the search for new sites, now that prime sites have already been taken, and the increased use of turbines by businesses and homes in urban areas as part of a reaction to high electricity prices and a desire to be energy independent.

To provide examples, in the last 5 years in Perth alone there have been installations on the Durack II building in the CBD, on the roof of the Bunnings warehouses in Rockingham and Port Kennedy, in the car park of the Toyota HQ building in Kewdale, on the roof of the City of Cockburn Council Offices, next to the Cottosloe Library etc. There have also been a number of recent cases where wind turbines in urban areas have received negative publicity due to very limited power production or even failure. In an extreme case in Hobart, police cordoned off the street when the blades of a building-mounted turbine broke in strong winds.

The performance of small wind turbines in the built-environment is strongly dependent on where they are sited. Poor location of the turbine results in poor power performances and, unfortunately, there are several examples in Australia where turbines sit idle for long periods of time because they have been installed in wind shadows.

In addition, there is strong evidence that turbine failures are linked to inadequate turbine design for the resource at the site. Many of these non-open sites are often characterised by highly turbulent wind flow, and there is a direct correlation between high turbulence intensity of wind and increased fatigue and reduced life of wind turbines. The current International Electrotechnical Committee (IEC) international design standards for wind turbines are based on wind turbines in open terrain and do not include design models for highly turbulent sites.

This PhD project is comprised of two parts. In the first part, an inexpensive method is proposed to gain insight into the wind conditions for a small wind turbine in the highly turbulent setting of the rooftop of a large building. The method provides both a wind resource assessment as well as guidance in micro siting wind turbines. For small wind turbine applications, particularly on the rooftop of buildings, conventional site measurements are not always useful due to the expense and difficulty in extrapolating the results to nearby locations. The aim of the first part of the project was to use Computational Fluid Dynamics (CFD) to simulate where wind turbines could be placed to maximise their efficiency. Through wind simulation in the target area, CFD helps to micro-site the turbine; finding the right location that will avoid re-circulation and shadow zones, and generate more power.

In the second part, a novel design turbulence model has been proposed that appears promising for use in a highly turbulent site. This new model shows a significant improvement in agreement with measured observations compared with the current turbulence model in the IEC design standards. This work is novel and innovative and has arisen through Murdoch's 5 year involvement with the International Energy Agency Wind Task 27, a unique network of wind research organisations, including the US Department of Energy's National Renewable Energy Laboratories (NREL). The aeroelastic code, FAST is used to assess the effect of a new turbulence model on the structural loading and fatigue of wind turbines. TurbSim, is a stochastic turbulence simulator allows the user to select a turbulence model and produces a 3D wind flow field with wind fluctuations governed by the model. FAST, is an aeroelastic code that uses the output of TurbSIM and computes the loading on selected wind turbines. Initial results suggest a significant increase in the blade root loading for a turbine installed at a highly turbulent site compared to open terrain. This illustrates the need for a dedicated design model for wind turbine manufacturers who intend their turbines to be used in the built environment in order to improve the performance, reliability and safety of wind turbines in such environments.

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

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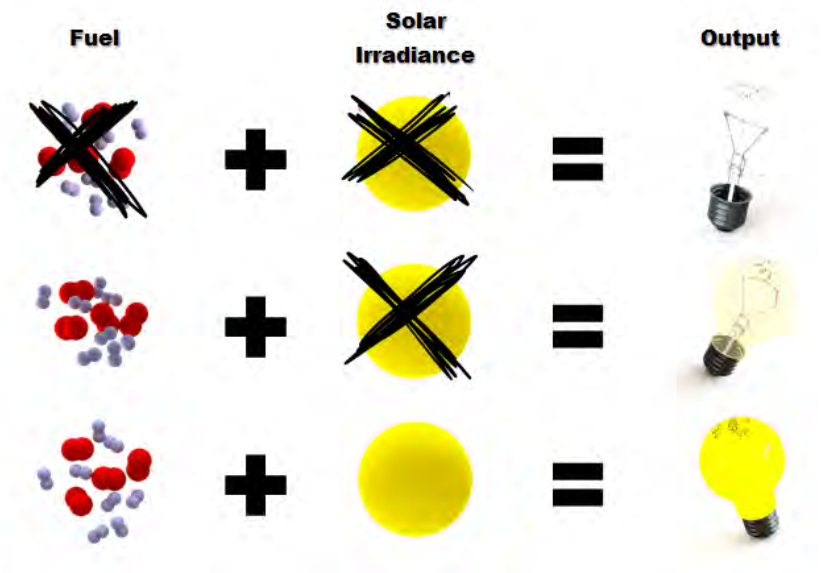
PROJECT SUMMARY:

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. Among these is the development of alternative materials for fuel cells. Present fuel cells very often use materials selected when fuel cells first gained interest, which 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 the catalyst one of the most expensive components of fuel cell. Other issue using platinum is CO poisoning where, platinum's catalytic properties are decreasing rapidly when it is exposed to carbon monoxide.



We present novel electro-catalyst based on polymeric alloys. Poly(3,4-ethylenedioxythiophene) (PEDOT) is a conductive polymer with great electro-catalytic properties (comparable to platinum) when used for oxygen reduction under alkaline conditions. Polythiophene is also a conductive polymer, widely used in solar cells, while poly(ethylene glycol) or PEG is very common material used in a range of application. When all three polymers are mixed together in a interpenetrating network, they create a hetero-junction material.

PEDOT acts 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 needed 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.

Initial tests show very promising results, which can be further improved by optimizing alloy's composition and using optimized fuel cell setup.

EVALUATION OF VICTORIAN BROWN COAL AS A FUEL FOR DIRECT CARBON FUEL CELLS (DCFC)

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PROJECT SUMMARY:

This research is a collaborative project involving the CSIRO and Monash University aiming at more efficient utilisation of Victorian brown coal than at present. CSIRO has been developing the direct carbon fuel cell (DCFC) technology since 2008, and Monash University has substantial capability in coal processing and characterisation.

DCFC's are the only fuel cell capable of operation on a solid fuel, and have projected overall system efficiencies of 60-70%, roughly twice that of existing coal fired power stations. In addition, the product gas is a concentrated CO_2 stream, ideal for CO_2 capture and storage. Brown coal chars are known to be reactive, have low ash content, and are promising candidates for DCFC fuels. However, the effect of the presence of mineral matter and solid trace metals in char on electrochemical performance is largely unknown. This project addresses these and other related issues.

Laboratory scale testing of partially charred coals from the Morwell mine has produced exceptional results, out-performing the benchmark synthetic carbon black fuel. The contribution of inorganic matter in Morwell coal, namely Ca, Fe, and Mg, to Boudouard gasification catalysis is well documented. Since CO_2 is the primary product of carbon consumption in the cell and is produced at the anode in the presence of the carbon fuel, a reactive char will convert the CO_2 to CO in a timely manner. This CO can then also be used by the cell as a fuel, generating additional current and CO_2, and setting up a cyclic mechanism in the gas phase. The parallel reactions of solid carbon consumption and gaseous CO consumption extend the fuel cell's performance to higher currents and power output.

Less reactive fuels such as carbon black are not able to capitalise on the gas phase reactions of the fuel cell, instead relying on the reaction of solid carbon particles in direct contact with the anode. A demineralised (acid washed) Morwell char was also produced and tested in the DCFC and performed similarly to the carbon black. The results of this study have been published in Applied Energy *(http://dx.doi.org/10.1016/j.apenergy.2014.01.046).*

CSIRO have developed the concept of using mixed ion electron conducting (MIEC) fuel electrode (anode) to shift the reaction zone from anode/electrolyte interface to anode/fuel interface specifically to cater for direct solid fuel reactions. Thus a family of new electrode materials has been developed by CSIRO to produce practical power densities. One of the anode materials that performed well with clean carbon fuels was found to be unstable with Morwell char and as a result new anode materials are now under development.

Work has also been performed at the Australian Synchrotron to investigate the stability of a range of anode materials in the presence of Morwell char and a new family of materials has been identified for the improved stability of the anode in DCFC environment.

This project is in the write-up phase and experimental work is being finalised. This includes the testing of carbon black doped with common inorganic impurities found in Morwell char to further understand the contribution of these components to cell performance. This study exploring the use of brown coal in a DCFC has resulted in three journal papers, with more to follow later on.

ALGAL BIODIESEL – THE ROLE OF CELL DISRUPTION IN LIPID RECOVERY

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PROJECT SUMMARY:

Fuel production from algae exploits the ability of algae to accumulate oil in the form of triacylglycerides (TAGs) using only sunlight, water and CO_2. Through the process of transesterification, these oils can be converted to biodiesel. Unlike terrestrial biomass feedstock, algal biomass can be generated at high areal productivities without competing with existing agriculture for arable land or fresh water. Despite generally favourable factors for algae as a biofuel producer, economic analyses of current process designs remain prohibitively expensive. This is largely due to the encapsulation of lipids within a rigid cell wall, resulting in a significant barrier to extraction and recovery. The primary step of intracellular lipid recovery for biodiesel production is the disruption of this cell wall barrier.

This work focuses on the disruption of wet *Nannochloropsis* sp. and *Chlorella* sp. biomass of up to 25 w/w% by high pressure homogenisation with subsequent lipid recovery by solvent extraction. While it is clear that cell disruption has a positive effect on lipid recovery, the extent to which this occurs and the underlying mechanisms are still not clear. Mechanisms of lipid recovery from disrupted cells were elucidated by subjecting algal suspensions to a range of homogenisation pressures prior to lipid extractions by monophasic and biphasic solvent systems. An investigation into the effect of feed variation such as solids concentration on the performance of homogenisation was also undertaken.

In this presentation, we present conclusive evidence of the need for complete cell rupture for an effective extraction and for the first time clearly describe the underlying mechanisms of solvent extraction from microalgae. An energy evaluation that demonstrates the feasibility of high pressure homogenisation will also be presented. This result is of particular importance to the development of algal biofuel as cell rupture is a critical processing step for which a scalable and efficient technique has yet to be established.

ENERGY MONITORING AND SMART GRID APPLICATION IN MANUFACTURING

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PROJECT SUMMARY:

The aim of this project is to enable optimal and reliable design, integration and operation of clean energy technologies within manufacturing facilities. In fact energy is a critical input for manufacturing industry to complete material transformation to the final products. However dramatic changes of energy market has challenged this industry to cope with rising costs. Moreover growing environmental awareness has shifted existing business strategies towards sustainability, to maximize added value with minimum resource consumption and environmental impact.

In this case on-site energy generation, through application of clean energy technologies, promises significant economic and environmental advantages. This can form a hybrid energy system consisting of controllable energy supply options such as combined heat and power (CHP) systems in presence of renewable technologies with intermittent output. However manufacturing facilities are faced with an on-going challenge to assure optimal and reliable integration of these technologies within their existing systems. In fact, fluctuation of energy demand trends due to the interaction of different processes and variable production plans in addition to high investment cost and potential dynamics and fluctuations of energy supply options result in a complex and dynamic system. Consequently under existing system design and operation management approaches expected system effectiveness can drop severely at the utilisation stage.

In our study, the value of integrated system sizing and operational strategy selection of the CHP system at the design stage has been evaluated. In this case required model improvements are identified and applied, which encompass the transient characteristics of the CHP system components and their operational constraints. In addition, the proposed methodology is generic enough to cover energy demand fluctuations of any existing manufacturing plant by aggregated data integration to guarantee improved outcomes. Finally the methodology is applied to the studied pharmaceutical manufacturing plant. The results illustrate promising potential improvements in comparison with existing approaches for CHP system configurations to maximum return on investment as well as reducing primary energy resource consumption and environmental impact.

On the other hand the project outcomes illustrate that at the operation stage, existing fixed operational strategies, such as thermal or electrical load following, cannot lead to optimal performance due to aforementioned system dynamics. Consequently continuous operation management of these systems, which can timely response to operating environment dynamics, is a key to enable maximised utilization of integrated assets. In this case, real-time optimization has shown promising potential to compensate shortages of existing operation management strategies. However lack of an applicable, reliable and comprehensive approach to conduct autonomous operation of these systems in real-time basis exists. Consequently in our study key requirements of autonomous operation management are identified. This would assure that continuous decision-making is aligned with operating environment dynamics as well as individual component's constraints. In this case an integrated simulation optimization methodology is proposed and evaluated by our group (SMLCE @ UNSW) for the existing manufacturing plant. This would adequately present operational behaviour both at component and system level and is capable to be applied iteratively to track a changing optimum as closely as possible. The latter should enable optimal and reliable integration of clean energy technologies especially renewable energy based ones with intermittent output within operating manufacturing plants.

In summary, this study covers both the business and technical aspects of on-site energy systems that should not only guarantee economical operation of integrated technologies but also assure required reliability and quality. This is achieved through identification of existing design, integration and operation challenges of on-site energy generation systems in industry. The latter encompass technical findings and existing shortcomings of the application of CHP technology within the studied manufacturing plant. Moreover particular problem modelling, which not only covers mechanical integrity of the components, but also address specific real-time application requirements, is achieved. The latter is simulated and tested for our case study, which illustrates potential of improvement and applicability compared to existing operation management approaches. Finally proposed approach would guarantee system reliability, unit commitment, and optimal operational objectives (operational cost, environmental impact and primary resource consumption) in a continuous manner. The latter should encompass not only energy demand dynamics but also intermittency of renewable energy technologies, which can play a vital role to result in their uptake at this sector.

AN EVALUATION OF ZIFS -8, -14 AND -71 FOR THE UPGRADING OF SOUR NATURAL GAS

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PROJECT SUMMARY:

In the current climate where there is increasing concern over greenhouse gas emissions and an increasing demand for energy, fuel switching is, and has gained attention. Fuel switching is where a given fuel is substituted for an alternative that has lower greenhouse gas emissions per unit energy produced. One of the more popular switches taking place currently is the change from coal fired power stations to natural gas fired generators. Consequently, this has contributed further to the increasing demand for natural gas.

It is estimated that approximately 40 % of the world's known natural gas reserves are sour. The high proportion of CO_2 or H_2S in these streams hinders the development of these resources. The H_2S in the stream must be removed as it may cause sulphide corrosion cracking in the transportation pipeline, and CO_2, while present with water, may cause corrosion problems.

This project focuses on the removal of CO_2 from high pressure natural gas stream, making them suitable for pipeline transport. This is typically taken as < 3 $\%_{mol}$ of CO_2. Currently, if the CO_2 content of a natural gas well is too high, it is not economically viable to separate it via the conventional amine technologies. This is due to the high cost of regeneration energy for the amine, as well as the associated solvent losses. We propose that pressure swing adsorption (PSA) is a suitable candidate for this task due to its negligible energy requirements and relatively simple process set up. This is opposed to other adsorption based technologies such as vacuum swing adsorption (VSA) and temperature swing adsorption (TSA), which have significant energy requirements compared to PSA.

The challenge associated with the PSA based separation lies with uncovering a suitable adsorbent material. As the feed pressure to the system will be high, the selectivity of many materials becomes low. Molecular sieving materials could be used for this separation, however, their kinetics are typically slow and would require large adsorbent beds. The majority of the research around CO_2 separation by adsorption in the recent time has focussed around flue gases, hence there is little high pressure adsorption data available on a range of materials.

In this work presented, we have synthesised and characterised a range of zeolitic imidazolate framework (ZIF) materials. These are ZIF-8, ZIF-14 and ZIF-71. ZIFs are a family of adsorbent materials which are similar to metal-organic frameworks (MOFs) except they have zeolite topologies. Single component adsorption isotherms have been measured at the analogous conditions, and PSA process simulation has been carried out over a range of feed CO_2 concentrations (15 – 35 $\%_{mol}$) in order to evaluate their performance over a range of possible scenarios.

A 9-step, 3-bed PSA cycle was opted for as it gives the opportunity to utilise pressure equalisation (PE) steps, of which there are two. For high pressure separations these steps are necessary in order to increase the recovery of the desired product as there is a significant amount of gas in the void space of the packed bed. This gas in the void spaces can also reduce the purity of the raffinate as it will dilute the stream. The system was simulated to operate at 100 bar feed pressure over a range of CO_2 feed compositions, and the intermediate step times and pressures were adjusted in order to obtain the best results for all three materials.

With the current choice of PSA cycle, ZIFs -8 and -71 demonstrate the ability to achieve the required CH_4 product purity. A more complex PSA cycle will be required in order to increase the recovery of methane to a level that will make the process more viable. The recovered CO_2 stream could then be sequestered or used for enhanced oil recovery. ZIF-14 is not able to provide a suitable separation at the desired conditions, and this is due to its very low CO_2/CH_4 selectivity.

RAROTONGA'S RENEWABLE ENERGY OPPORTUNITIES

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Department: International Energy Centre

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PROJECT SUMMARY:

The Cook Islands is a group of small islands in the Pacific with an ambitious target of providing 100% of power generation from renewable sources by 2020. The island nation is currently reliant on imported diesel and subsequently vulnerable to supply and price fluctuations. In addition, dependency on expensive fossil fuels is hindering growth prospects, and leaves the country exposed to environmental, social, and economic risk factors.

The capital island, Rarotonga, is the nation's economic hub with a peak electricity demand of 5MW, which is entirely generated from fossil fuels. The key issue with integrating renewable energy into the current system is its inherent variability, which would negatively affect grid stability. This project investigates options for an innovative renewable energy solution in three phases: (1) a technical-economic assessment of generation technologies (including pumped hydro with storage, solar PV and thermal, wind, near-shore wave, and biomass); (2) real options valuation for capital investment in the three most attractive technologies; and (3) a social impact assessment. Particular attention will be made to the vulnerability of the energy system to global climate change and the increasing occurrence of cyclonic events in the region.

The goal of the project is to provide realistic data on energy scenarios for the Cook Islands to inform development finance agencies and commercial investors. It is likely that effective, efficient, and equitable sustainable development in the Pacific will require hybrid finance mechanisms and the collaboration of public and private organisations. The interdisciplinary approach taken in this project will support this outcome.

Rarotonga is not alone in the pacific region in regards to its dependence on imported fossil fuels and as such the method to identifying an integrated renewable energy solution for the island will be assessed for its transferability to similar island states. The project is expected to provide not only a potential direction for Rarotonga but serve as a template for other nations to assess their own energy reform options.

This research is conducted as a Professional Project in the Master of Energy Studies program. The Professional Project component is equivalent to a Master's level thesis (one semester full time with a 14,000 word report), and involves advanced applied research conducted to academically rigorous standards in association with a host or partner organization. In this case the research will be pursued in collaboration with the Cook Islands power authority Te Aponga Uira (TAU) and New Zealand engineering consultancy Fraser Thomas Limited. The timeframe for the work comprises 3 stages: (1) literature review and preparatory communications; (2) in-country data collection; and (3) analysis and reporting. The project is currently in the first stage, and the final report is due to be delivered at the beginning of June 2015.

DETERMINATION OF CEMENTATION EXPONENT (M) IN GAS SHALE RESERVOIRS

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Department: Department of Petroleum Engineering

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PROJECT SUMMARY:

The main target of this research is to develop new laboratory technics for determination of cementation exponent in shaly formations and consequently; calculating more accurate hydrocarbon saturations in gas shale reservoirs.

Cementation Exponent (m) is one of the most important factors in calculation of hydrocarbon saturation in oil and gas reservoirs. Cementation exponent defines how pore spaces are connected to each other. In the Archie formula ($S_w=\sqrt{((aR_w)/(\phi^m R_t))}$) cementation exponent (m) acts as the power of porosity term (ϕ), therefore, any small error in m; result in erroneous calculation of fluid saturation (Tabibi & Emadi, 2003). Due to shale complex composition and its ultra-low permeability, cementation exponent determination is a complex process. Limitations that can be expected for electrical conductivity measurements incudes: difficulties in cutting shale core samples and sample preparations, flooding and fully saturating of shale core plugs, cracking samples during high pressure flooding, drying sample water without damaging and laboratory measurements of resistivity of shale core samples.

The aim of this research is to develop new laboratory technics for determination of cementation exponent and to provide a reliable range of “m” to use in petrophysical interpretation of gas shale reservoirs. In addition, new findings of core flooding technics and measurements of Formation Factor in shale samples are anticipated.

THE IMPACT OF WATER ON THE PERFORMANCE OF CELLULOSE ACETATE MEMBRANE FOR CARBON DIOXIDE SEPARATION

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PROJECT SUMMARY:

The sustainable development of coal-fired power generation requires the effective control of emissions by modern technologies. Specifically, coal demand is one of the essential resources that is expected to occupy over one-third of the global electricity market in the next decades. Several valuable commodities produced from brown coal are also competitive to replace more cost intensive fossil fuel products.

Membrane separation is outstanding in carbon dioxide (CO_2) capture with advantages in energy efficiency, land footprint and the absence of chemical consumption. However, the accelerating utilisation of brown coal will result in the increase of flue gases that are contaminated with water at high pH. The presence of water reduces the performance of the membrane by plasticisation, clustering as well as competitive sorption. Therefore, the study of the water impact on membrane performance is essential to achieve the sustainable development of brown coal.

Dense cellulose triacetate (CTA) membranes have been widely utilised in industrial gas separation processes. The commercial readiness makes CTA an ideal candidate in capturing carbon dioxide (CO_2). Although the manufacture of membrane modules for CTA is well developed, the effect of water vapour s still not fully understood. This poster comprises a review of the impact of water on CTA in both membrane permeation and sorption kinetics. The study also investigates the impact of water on the performance of a CTA membrane at pH 12.8 that is the practical flue gas condition in current coal-fired power stations. The kinetic sorption, gas separation performance and chemostability of CTA were studied. It is found that the existence of highly alkaline conditions decomposes the membrane structure and thus increases the membrane diffusivity and solubility.

TECHNO-ECONOMIC PRE-ASSESMENT OF WASTE-TO-FUEL PROCESSING IN ACT

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PROJECT SUMMARY:

Waste-to-energy, particularly the gasification of waste to produce transport fuels, is increasingly attracting the attention of researchers in Australia and overseas. The potential to significantly reduce negative impact of waste on the environment, combined with opportunities to generate sustainable sources of transport fuels and power, is the major driver of these efforts. Whilst the Australian Capital Territory has significantly reduced waste to landfill over the last twenty years, ACT waste streams are still of sufficient quality and quantity to justify studying the potential for low carbon waste-to-energy projects. In particular, the ACT Government is interested in a potential conversion of waste to transport fuels. Accordingly, the Environmental and Sustainable Development Directorate (ESDD) has asked the ANU Energy Change Institute (ECI) to undertake a preliminary study reviewing technical and economic possibilities for the production of a sustainable transport fuel through the utilisation of the Territory's waste streams. The specific question can be framed as follows:

- What are the practically viable technologies and processes available to convert the ACT waste streams into fuel and to what extent are these commercially viable?

To address the qualitative and the quantitative aspects of this research question, the study follows the fundamental principles of mixed research methodology and accordingly:

- Provides an overview of existing gasification technologies i.e. Entrained Flow Gasifiers (EF), Bubbling Fluidised Gasifiers (BFB), Circulating Fluidised Bed Gasifiers (CFB) and Plasma Gasifiers (PG)
- Investigates pathways which are commercially available. These include biochemical and thermochemical pathways of producing transport fuels through gasification of waste
- Analyses options with the greatest potential for local production of high quality sustainable transport fuel through parameters such as specific feedstock requirements, potential to achieve the syngas quality in terms of the ratio of H_2:CO, development status & operating experience and overall costs incurred
- Outlines components of synthetic gas (syngas) produced as a result of gasification of ACT waste through comparing various commercially available syngas cleaning units based on their ability to produce syngas of the quality required for use in internal combustion engines, with a special emphasis on managing tar and particle content

Accordingly, the project proposes an optimal syngas treatment process flow sheet comprising of a plasma unit, a quencher, a wet electrostatic precipitator, a water shift reactor, and an acid remover. This proposed process train is expected to suit all types of gasifiers ranging from conventional systems to modern plasma gasifiers. Finally, economic aspects of the proposed arrangements are considered.

ENERNET OF THINGS: DEMAND SIDE MANAGEMENT FOR SMART GRID USING GAME THEORY AND BIG DATA ANALYTICS

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PROJECT SUMMARY:

To ensure reliability, traditional electricity systems are built with redundant generation, transmission and distribution capacity such that they are able to withstand the peak demand. However, structuring the electricity system in this way (having supply to match demand) is inefficient. A significant portion of generation, transmission and distribution capacity is under-utilized or sitting idle for most of the time. In Victoria, 2012, 40% of the grid is only used for 10% of the time or less and the situation is getting worse. What's more, unpredictable demand could have a huge impact on electricity wholesale price. During hot summer days in Victoria, Australia, the highest wholesale price can be 200 times more than the average price which in turn drives up retail price. On the other hand, a large portion (more than half) of the electrical power demand is used for applications with significant battery or thermal energy storage (e.g. space heating, electric vehicles). Hence, there is significant potential for Demand Side Management (DSM) to a) help increase the efficient use of electricity grid assets; b) unlock the storage capacity of appliances and reduce peak demand; and c) reduce overall electricity retail price.

DSM commonly refers to technologies deployed by distributors or consumers to achieve certain management goal by controlling electricity consumption pattern at the demand side. In simple terms, through local management, we want to have network demand to match supply. Conventional DSM solutions such as Direct Load Control may affect users' behaviour. We are designing a solution framework for low voltage (LV) that shifts users' demand in time domain rather than forcing the consumption to cease. Apart from that, we want the solution to be able to perform power factor correction locally, to help with network unbalance reduction, to overcome the intermittency brought by distributed generations, etc.

In order to do so, on the infrastructure level, we propose a new terminology – 'EnerNet' which is the combination of Internet, electricity grid and grid Information and Communication Technology (ICT) infrastructure. Modern appliances have/will have Wi-Fi connectivity. Assume most appliances are connected to the Internet. By analysing consumption data, users' preferences can be interpreted and future demand can be forecasted. Using this information, the distributors can design tariffs accordingly and calculate dynamic prices; the consumers can make better control actions. Having the infrastructure and data available, on the algorithm level, the problem will be modelled as a constraint optimization problem where the benefits of both distributors and consumers will be jointly optimized. In terms of distributed implementation of the optimized solution, we propose a game theoretic approach. In simple terms, the distributor will calculate broadcast a price that reflects how the key constraints in a network are violated every few minutes. The user who receives this signal will perform a local game theoretic optimization for decision making. For a simple example, if the signal suggests that the network is relatively free and from the cloud a user knows that a peak is coming, certain appliances such as air conditioners, water heaters or even electric vehicles will act aggressively in a way that when the demand peaks, they are able to supress their power to alleviate peaks. As a result, the user pays much less than before and in a long run, the distributors get more out of the infrastructure.

In terms of simulation and verification, we have built network models of real Australian suburban network in SIMULINK based on data provided by various distributors. The models take into consideration aspects such as power factors, phase unbalance, distribution line impedance which is commonly neglected in most DSM literatures. The simulations have shown some promising results and I have already published some initial findings as first author in IEEE PES conferences and the IFAC World Congress.

THE ROLE OF INHERENT MOISTURE ON BROWN COAL IGNITION DURING OXY-FUEL COMBUSTION

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PROJECT SUMMARY:

Almost 85-90% of the electricity generated in Victoria comes from burning brown coal in coal-fired power station. This low-rank coal finds attractive in power generation due to low sulphur content, low-cost and abundant. However, Victorian brown coal contains roughly 60%-70% moisture in its as-mined state. The direct-use of wet coal in coal-fired power plant may not be energy-efficient as the latent heat of vaporization is not recovered. In addition, it also further increases the emission of CO_2 to the atmosphere to the value of ~1.5 times more compared to burning the high-grade bituminous coal. Upon the restrain on CO_2 emission, there is an urgent need in brown coal industry to deploy the next generation low-emission technology, such as oxy-fuel combustion. The fundamental understanding of wet brown coal combustion in oxy-fuel combustion is essential, for the purpose of retrofitting oxy-fuel furnace as well as deployment of coal-blending technology with high-rank coal.

Oxy-Fuel Combustion is a process of burning coal in the mixture of high-purity oxygen and recirculated flue gas (RFG) to generate a capture-ready CO2-rich stream from power plant. For the Victorian brown coal with a >500-year reserve in Victoria, its abundant moisture content (up to 70 wt%) is a critical factor affecting its combustion, either in conventional air or oxy-fuel combustion process. On the one hand, a partially dried coal brings moisture with it into a boiler, which is supposed to cause ignition delay and reduce flame temperature. On the other hand, upon the recirculation of flue gas in oxy-fuel process, the steam entrained by the RFG, if not fully condense, will be gradually accumulated in the boiler. The higher specific heat of steam and CO_2 in oxy-combustion will affect the heat flux in a conventional boiler, which is rich in N_2. It will also affect the carbon burnout extent compared to conventional air combustion as the results from gasification reaction.

In this study, the ignition and combustion behaviour of wet brown coal were investigated in conventional air and oxy-fuel atmosphere using imaging technique and non-intrusive in-situ optical diagnostic technique for particle temperature measurement. A one-dimensional mathematical model was also developed to accurately justify the fate of moisture in this high temperature condition. Current coal drying mechanism was simplified as a separate mechanism with no overlap to the subsequent devolatilisation and char combustion stage, as applied in the commercial Computational Fluid Dynamic (CFD) software. The experiment in Monash flat-flame burner reactor has justified different flame pattern of dried and wet coal, particularly in oxy-fuel condition. If the moisture has been completely released, there should be an initial ignition delay due to moisture evaporation and no significant difference at the subsequent devolatilisation and char oxidation regime. Clearly, that was not the case for wet coal.

The use of mathematical model, comprising of coal-drying, single kinetic devolatilisation rate equation and multiple-surface reaction single-film model for char oxidation prediction has successfully clarified this phenomena. The moisture was subjected to trigger the endothermic char-steam gasification which lowers the burning particle temperature. Therefore, the influence of moisture was clarified via matching the predicted particle temperature with the measured particle temperature using the infrared pyrometer. The moisture residing in wet coal triggered the char-steam gasification reaction at 21% oxygen in oxy-fuel atmosphere and was counter-balanced by increasing the oxygen concentration up to 31% in oxy-fuel. These results demonstrated that higher oxygen concentration was needed when burning wet coal in the coal-firing furnace. The operating condition will need to be further optimized to estimate the amount of oxygen needed in real oxy-firing furnace, which is rich in steam due to continuous flue gas recycle.

AN ELITE VARIETY OF ALGAE FOR FEED AND BIOFUEL

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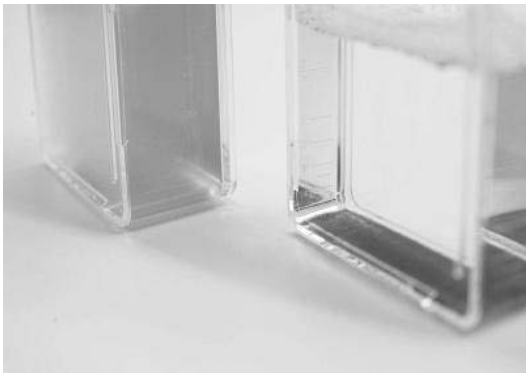
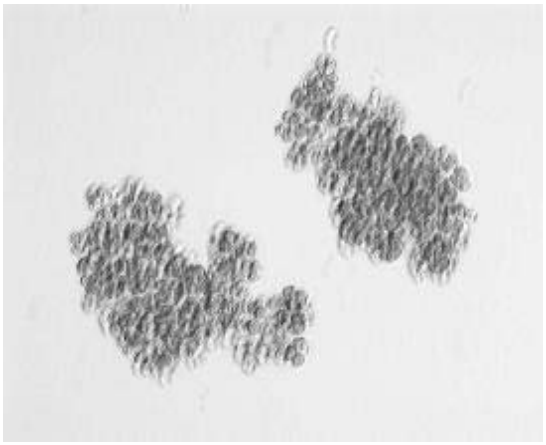
PROJECT SUMMARY:



I have developed an elite strain of algae that now makes the low cost and economical production of food and fuels via algal farming a feasible endeavour. It is the culmination of 3 years of research and development whereby it possesses a host of ideal characteristics for lowering overall production costs. This strain is a non-GMO variety that was developed via the natural method of selective breeding.

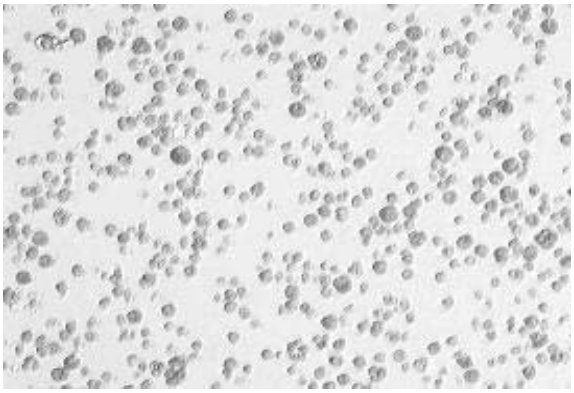
The key traits that set this strain apart from other industrially relevant strains are:

(1) Easily harvestable. This significantly lowers the cost of the most expensive part of algae farming, which is the separation of the microscopic algae cells from the water in the pond. This is due to its capability of autoflocculation, which results in the microscopic cells aggregating into large clumps and thereby making them very easily filtered and captured, with cloth for example.



(2) Growth in saltwater. This allows for scalability and therefore lowered production costs through economies of scale. This is because seawater can be used for the ponds, which is beneficial because there is an abundant supply and also our precious freshwater is better conserved.

(3) Mixotrophic growth. It can grow using organic carbon sources, which essentially allows for the use of very cheap organic fertilisers for more productive growth. This strain is also ideal for wastewater remediation because it removes Ammonia, Phosphorous, Sulphur compounds and more.



(4) Highly adaptable. This trait is distinctive to this organism and is imperative for the economic success of algal farming. Unlike all other industrial strains, this is a domesticated strain that has a superior ability to adapt and remain productive in any climate or farming condition that it is exposed to.

Although other industrial strains may possess some of the aforementioned traits, none possess the full host. @TheAlgaeBreeder

INVESTIGATING THE OXIDATION OF SYNTHETIC JET FUELS WITH TWO-DIMENSIONAL GAS CHROMATOGRAPHY

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PROJECT SUMMARY:

The increasing cost and scarcity of fossil fuels, along with environmental and fuel security concerns has prompted increased interest in alternative liquid transport fuels. Whilst many commercial, industrial and domestic uses of liquid fuels can be replaced with other renewable energy sources, this is generally not plausible for aircraft. Jet fuel production accounts for a significant proportion of fossil fuel use, and fixed and rotary-winged aircraft require an energy-dense, low mass energy source which is only likely to be met by liquid hydrocarbon fuels with current technologies. Compatibility with existing equipment and infrastructure is also a key consideration.

In modern jet aircraft, fuels are subjected to increasingly high thermal loads, particularly where fuel is used as a heat sink for the cooling of avionics and lubricants. When these fuels are subjected to thermal stress, their tendency to form gums and other insoluble deposits is enhanced, as is an increased propensity towards poor fuel quality parameters such as water separability and surfactant tendency. These factors are directly related to the fuel's thermal stability, which is essentially its ability to resist oxidation reactions.

The thermal stability of alternatively-derived jet fuels is known to be poor in comparison with those from conventional sources. These negative effects can be attributed to the formation of oxidised species in the fuel. The molecular complexity of fuels makes it difficult to undertake detailed studies of oxidation products in thermally stressed fuels, however, advanced analytical chemistry techniques such as multidimensional gas chromatography can go some way to alleviating these problems.

Here, two-dimensional gas chromatographic techniques have been used to analyse the different classes of oxidised species in thermally stressed jet fuels (Figure 1), as well as quantify concentrations as a function of time (Figure 2). Clear differences were observed between the conventional and alternative jet fuels, regarding the types and amounts of oxidised species produced over a period of thermal stressing. Some key oxygenated compounds have been identified in both fuels that are likely to contribute to poor fuel thermal stability.

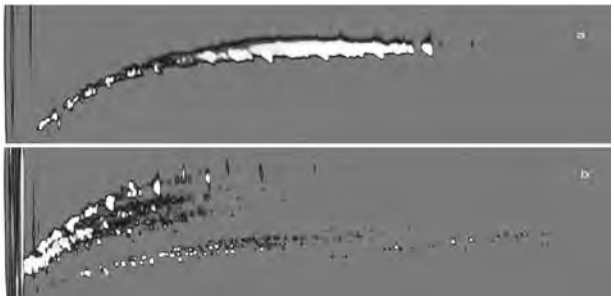

Figure 1. Comprehensive gas chromatogram of (a) neat alternative jet fuel; (b) the same fuel after thermal stressing.

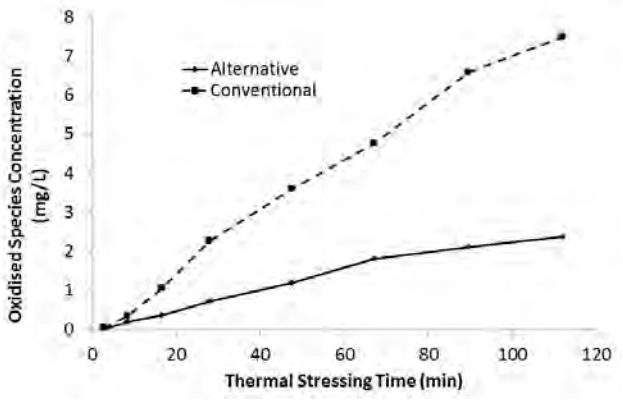

Figure 2. Increasing concentration of oxidised species over thermal stressing period of alternative and conventional jet fuels.

RATE BASED MODELLING OF POTASSIUM CARBONATE (K_2CO_3) PRECIPITATING ABSORPTION COLUMNS IN CARBON CAPTURE

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PROJECT SUMMARY:

The use of potassium carbonate (K_2CO_3) solvent in carbon dioxide (CO_2) capture processes, especially for removing CO_2 from flue gases in coal-fired power plants, has gained momentum in recent years. CO_2 absorption efficiency can be improved by using higher K_2CO_3 concentration, and simultaneously the precipitation of potassium bicarbonate ($KHCO_3$) at higher K_2CO_3 concentration will reduce the solvent circulation rate and thus lowering the cost on solvent regeneration equipment and regeneration energy. However, due to systematic stability and operating difficulty, the concentration of K_2CO_3 solvent was limited below 30 wt% in the industry to avoid the precipitation phenomena during CO_2 capture process. The kinetics in low K_2CO_3 concentration solvent for CO_2 capture process has been studied extensively using experimental and numerical techniques, studies of high K_2CO_3 concentration with precipitation have been neglected.

In order to model a rate-based precipitating absorption column regarding to this case, a review of high K_2CO_3 concentration based CO_2 absorption processes has been conducted, along with a kinetics study on $KHCO_3$ precipitating process including crystal nucleation rate and growth rate. In addition, validation of thermodynamics of CO_2 capture based on high concentration of K_2CO_3 solvent has been investigated in Aspen Plus using an Electron Non Random Two Liquid (ENRTL) model on CO_2-K_2CO_3-$KHCO_3$-H_2O Vapour-Solid-Liquid-Equilibrium (VSLE) system. Furthermore, modelling of rate-based CO_2 absorption column involving vapour, liquid and solid phases will be investigated and studied by coding in Aspen Custom modeller, and then embedded into Aspen Plus to simulate the carbon capture process at a high K_2CO_3 concentration.

The purpose of this work is to develop a rate-based precipitating absorber model which could further support the high concentration of K_2CO_3 based solvent system with a range of promoters. This is expected to be incorporated into a full plant design, improve the accuracy of optimisation studies and scale-up simulations of high concentration solvent CO_2 absorption process, which provides guidelines on how to overcome operational instability and operating issues of precipitating process. By using this innovative method in CO_2 absorption, the energy consumption in the precipitating system with high K_2CO_3 concentration is expected to be reduced by 20% compared to a general solvent system with low K_2CO_3 concentration.

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