11th RENEWABLE ENERGY POSTGRADUATE STUDENTS *e*-SYMPOSIUM

CENTRE FOR RENEWABLE AND SUSTAINABLE ENERGY STUDIES

North-West University

21 September 2020

BOOK OF ABSTRACTS

Students who are interested to participate are requested to e-mail their abstracts and contact information to Prof Sanette Marx by 25 May 2020 at sanette.marx@nwu.ac.za or contact her on 018 299 1995.

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Table of Content

Abstracts of specific presenters can be accessed by clicking on the name of the presenter in the Program Overview

Virtual conference arrangements

General Info

The conference is presented through the MS Teams software that forms part of the institutional Microsoft software suite. Arrangements put in place during the stricter COVID-19 lockdown periods ensure the lowest possible data usage for this software.

Participants in the symposium (session chairpersons, presenters and attendees) can access any of the sessions during the symposium by simply clicking on the name of any of the presenters in the session on the web links in the program overview. Links for each session will be emailed to presenters and session chairpersons.

Presenters and chairpersons

We ask that all presenters and session chairpersons tune into their respective sessions at least 10 minutes before the start of the specific session. This is to allow IT support to verify that all presenters are present and to explain the screen sharing and Q&A procedures. Should load shedding and/or internet connection problems prevent a live presentation, IT support will share and play the recorded presentation. All presenters are reminded that each presentation slot is only 12 minutes long with 3 minutes for Q&A. Time limits will be adhered to strictly to ensure that all presenters have a reasonable time to present their work. Presenters and chairpersons are encouraged to make use of a headset with a microphone for best audio during the session.

Attendees

Persons not linked as a session chairperson or a presenter for a specific session will be allowed into the session as an attendee. Attendees cannot share screens or ask questions verbally. All questions and answers can be submitted through the Q&A tool. The session chairperson will attend to all questions at the end of each presentation. Should there be many questions, presenters can continue to answer questions through the Q&A tool until the end of the session. Please be advised that some time delays in the Q&A might be experienced due to buffering, depending on the strength of individual internet connections and computer processing speed. All sessions will take place live and in real time. We recommend that attendees ensure a stable and strong internet connection with a computer that are able to stream live without too much buffering. A set of headphones are also recommended for best audio.

Accessing MS Teams software

Presenters and session chairpersons will receive a link they can access to enter their respective live sessions. Attendees can access through the links on the web page by clicking on any of the names of the presenters in the session they wish to attend.

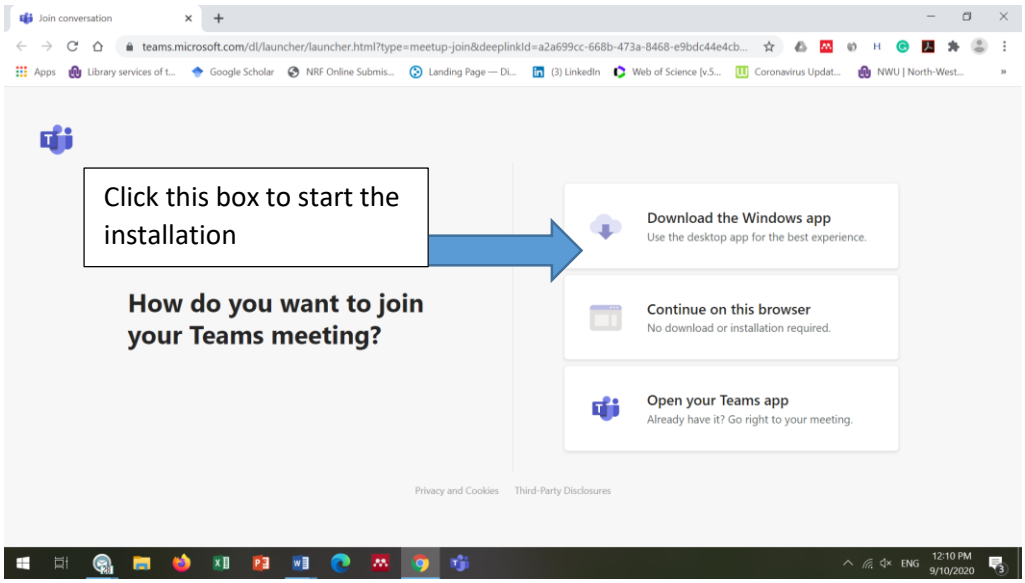
Software installation and use

STEP 1

Once you click on the link (either the email or web link), Windows will prompt you to install the free version of MS Teams. **You do not need to buy the software** to be able to attend or participate as a presenter or session chairperson in this symposium. You should see the screen below. (Attendees can join the sessions as an anonymous viewer by viewing through the web. In that case, no installation of the software is required).

For software installation, click on the "Download the Windows App" box to start the installation (you can use the freeware version). You will need to register to use the software. You can do that through a google account, Facebook account or your Microsoft account.

NB! Please make sure you install the software well before the symposium starts.



STEP2

For presenters and session chairpersons

If you already have MS Teams installed and are logged in:

Click on either the blue link in the email you received (presenters or session chairperson) or on the web link to access the sessions

NWU students should log in with:

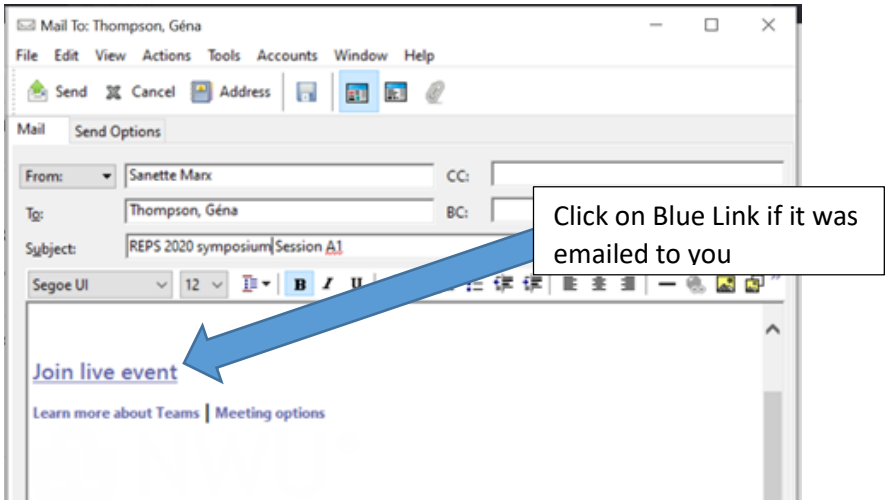
Username: studentenumber@student365.msfed.nwu.ac.za

Password: Your NWU network password

NWU staff should log in with:

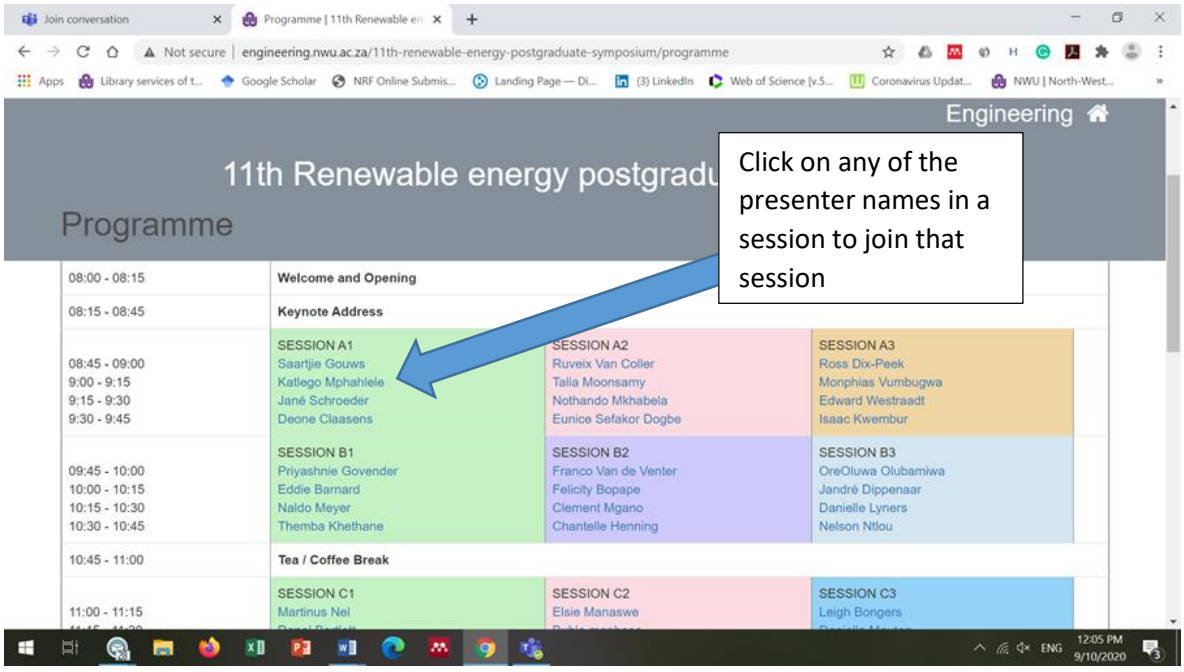
Username: staffnumber@staff365.msfed.nwu.ac.za

Password: Your NWU network password



For attendees

Click on the web page Link (web page will become accessible only closer to the event). You can also opt to attend the sessions through the web, but that might use more data.



Each session has a dedicated “IT” support person that will be responsible for making sure presentations are published live to the audience. Below are the contact details of the IT support staff for each session. You can email them should there be any problems that cannot be addressed through the MS Teams software before, during or after each session.

11th Renewable Energy Postgraduate Student Symposium

IT Support staff

Time slot	TRACK 1	TRACK 2	TRACK 3
8:00 – 8:15	WELCOME AND OPENING – Prof Sanette Marx/Prof John Bunt		
8:15 – 8:45	KEYNOTE ADDRESS – Dr Karen Surridge (SANEDI)		
	SESSION A1 / **SESSION A2**		**SESSION A3**
8:45 – 9:45	Prof Sanette Marx sanette.marx@nwu.ac.za	Mr Winroe meyer winroemeyer@gmail.com	Dr LC Muller 24023795@nwu.ac.za
	SESSION B1	**SESSION B2**	**SESSION B3**
9:45– 10:45	Prof Sanette Marx sanette.marx@nwu.ac.za	Mr Winroe meyer winroemeyer@gmail.com	Dr LC Muller 24023795@nwu.ac.za
	SESSION C1	**SESSION C2**	**SESSION C3**
11:00 – 12:00	Me Saartie Gouws sgouws234@gmail.com	Me Felicity Bopaper 22832785@nwu.ac.za	Mr Hermanus Marais maansmaraisjnr@gmail.com
	SESSION D1	**SESSION D2**	**SESSION D3**
12:00 – 12:45	Me Saartie Gouws sgouws234@gmail.com	Me Nthabiseng Leokaoke Nthabiseng.leokaoke@nwu.ac.za	Mr Hermanus Marais maansmaraisjnr@gmail.com
	SESSION E1	**SESSION E2**	**SESSION E3**
14:00 – 14:45	Mr Winroe meyer winroemeyer@gmail.com	Me Felicity Bopaper 22832785@nwu.ac.za	Dr LC Muller 24023795@nwu.ac.za
14:45 - 15:00	SUMMARY – Prof Sanette Marx		
15:00	CLOSURE – Prof S Mamphweli		

11th Renewable Energy Postgraduate Student Symposium

Session Chairpersons

Time slot	TRACK 1	TRACK 2	TRACK 3
8:00 – 8:15	WELCOME AND OPENING – Prof Sanette Marx/Prof John Bunt		
8:15 – 8:45	KEYNOTE ADDRESS – Dr Karen Surridge (SANEDI)		
	SESSION A1	**SESSION A2**	**SESSION A3**
8:45 – 9:45	Prof Johan Görgens Dr Roelf Venter	Prof Quentin Campbell Mr N. Mararakanye	Dr WJ Smit Dr J Crozier McCleland (TBC)
	SESSION B1	**SESSION B2**	**SESSION B3**
9:45– 10:45	Prof Hein Neomagus Dr S Farzad	Prof Ray Everson Prof Marco le Roux	Matthew Groch Dr Nathie Gule
	SESSION C1	**SESSION C2**	**SESSION C3**
11:00 – 12:00	Prof Peter Osifo Dr LC Muller	Dr MJ Chihota Mr Ruveix van Coller	Prof B Akinyemi (TBC) Dr Bernard Bekker
	SESSION D1	**SESSION D2**	**SESSION D3**
12:00 – 12:45	Prof Sanette Marx Prof Patrick Mukumba	Dr Mandegari Prof Christien Strydom	Prof Fumane Lehoko (TBC) Prof Ernest van Dyk
	SESSION E1	**SESSION E2**	**SESSION E3**
14:00 – 14:45	Me N Leokaoke Dr Henry Matjie	Prof John Bunt Prof Dawie Branken	Prof MJ Kamper Prof HJ Vermeulen
14:45 - 15:00	SUMMARY – Prof Sanette Marx		
15:00	CLOSURE – Porf S Mamphweli (TBC)		

	Biomass energy
	Techno-economic/LCA
	Clean Coal
	Carbon capture and storage
	Solar energy
	Wind
	Electricity grid
	Industrial

11th Renewable Energy Postgraduate Student Symposium

Program overview

Time slot	TRACK 1	TRACK 2	TRACK 3
8:00 – 8:15	**WELCOME AND OPENING** (Prof Sanette Marx and Prof John Bunt)		
8:15 – 8:45	**KEYNOTE ADDRESS** (Dr Karen Surridge – SANEDI)		
	SESSION A1	**SESSION A2**	**SESSION A3**
8:45 – 9:00	Saartjie Gouws	Ruveix Van Coller	Ross Dix-Peek
9:00 – 9:15	Katlego Mphahlele	Talia Moonsamy	Monphias Vumbugwa
9:15 – 9:30	Jané Schroeder	Nothando Mkhabela	Isaac Kwembur
9:30 – 9:45	Deone Claasens	Eunice Sefakor Dogbe	
	SESSION B1	**SESSION B2**	**SESSION B3**
09:45 – 10:00	Naldo Meyer	Franco Van de Venter	OreOluwa Olubamiwa
10:00 – 10:15	Themba Khethane	Felicity Bopape	Jandré Dippenaar
10:15 – 10:30	Rhulani Ntimbani	Clement Mgano	Danielle Lyners
10:30 – 10:45	Edson Chimbazaza	Chantelle Henning	Nelson Ntlou
10:45 – 11:00	**TEA BREAK**		
	SESSION C1	**SESSION C2**	**SESSION C3**
11:00 - 11:15	Martinus Nel	Elsie Manaswe	Leigh Bongers
11:15 - 11:30	Danel Bartlett	Buhle Maphosa	Daniello Mouton
11:30 - 11:45	Gidoen Van Rensburg	Siphesihle Mbatha	Lukas Van Eck
11:45 - 12:00	Wilden Stokes	Danie Diedericks	Ria Xavier
	SESSION D1	**SESSION D2**	**SESSION D3**
12:00 - 12:15	Portia Mafu	Gerhardt Coetzee	Schalk Lombard
12:15 - 12:30	Rudzani Netshivhumbe	David Van der Berg	Matthew Meas
12: 30 - 12:45	Niel Bezuidenhout	LC Muller	Milan Swart
12:45 – 14:00	**LUNCH**		
	SESSION E1	**SESSION E2**	**SESSION E3**
14:00 - 14:15	Wellington Arthur	Lawrence Koech	Pangomsa Ntonjane
14;15 - 14:30	Oseweuba Okoro	Andre Jacobs	Nothando Mkhabela
14:30 - 14:45	Hermanus Marais	Louis Wentzel	Tshuma Phakamani
15:45 – 15:00	**SUMMARY** (Prof Sanette Marx/Prof Hein Neomagus)		
15:00	**CLOSURE** (Prof Samson Mamphweli – Director CRSES)		

	Biomass energy
	Techno-economic/LCA
	Clean Coal
	Carbon capture and storage
	Solar energy
	Wind
	Electricity grid
	Industrial

Condensables derived from pyrolysis of coal and torrefied biomass at elevated pressures

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Abstract

The addition of torrefied biomass to coal-based thermochemical conversion processes significantly reduces the carbon footprint of the overall process. Although commercial gasifiers are operated at high pressures, limited studies on co-pyrolysis at high pressures are available. The effect of pressure will be an important variable to consider when modelling the condensable products formed during co-pyrolysis. The aim of the study is to describe the evolution behaviour of condensables produced during co-pyrolysis of torrefied biomass and coal at elevated pressures. In this study, the fuel properties of wood chips were improved prior to the pyrolysis process by performing bulk torrefaction in a rotary kiln at a temperature of 280°C. The pyrolysis was performed at pressures of 1, 15 and 30 bar in a fixed bed reactor. The condensables were collected and subsequently analyzed by GC-MS. Results showed that the char yield increased slightly with pressure, however the pressure had a more significant effect on the distribution of volatile components into either liquid or gas. At a higher pressure, the gas yields increased whereas the liquid yield decreased. Higher pressure resulted in an increase in the intra-particle residence time of volatiles which gave rise to an increase in the extent of cross-linking and cracking reactions. A reaction scheme was developed to describe the condensable products formed during pyrolysis of torrefied biomass. In future work this scheme will be used to model the co-pyrolysis process.

Keywords: Torrefaction, biomass, coal, pyrolysis, modelling

SESSION A1: BIO-ENERGY

Optimisation of volatile yields from thermogravimetric analysis of Gauteng sewage sludge (GSS) using central composite design

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[b]Energy Systems, School of Chemical and Minerals Engineering, North-West University, Potchefstroom 2520, Republic of South Africa

Abstract

Conventional disposal methods of GSS involve landfill, incineration, and application in agricultural activities. Drawbacks which are involved in using the conventional methods of disposal have created an interest in application of thermo-chemical processes such as gasification and pyrolysis for production of fuel and value-added chemicals. In this regard, extensive research has been conducted on the main effects of operating conditions on the yields of volatiles from the GSS pyrolysis. An oversight has been made on combined effects of operating conditions and optimisation of process parameters. The current study aims to use central composite design (CCD) and one-way analysis of variance to optimise the operating conditions for maximum volatile yield. The degree of main and combined effects of heating rate and particle size on the yield of volatiles was subsequently evaluated.

Conclusions and recommendation will be drawn on the preliminary results obtained from the characterisation study, thermal degradation characteristics of sewage sludge, statistical analysis, perturbation plots, optimisation solutions and desirability using Design Expert™ software.

Keywords: GSS; central composite design; thermogravimetric analysis

SESSION A1: BIO-ENERGY

Steam gasification kinetics of biochar at elevated pressures

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Abstract

Coal remains a valuable resource in the generation of energy and transportation fuels, however the world's coal resources are depleting and its impact on the environment and human health raises concern. The investigation into alternative resources such as biomass, have become more relevant. One of the most promising processes for biomass utilization is gasification. Commercially in South Africa, the gasification process is performed at elevated pressures in fixed-bed dry bottom gasifiers. This process is considered fuel flexible and suited for the co-processing of coal and biomass. This project studies the steam gasification kinetics at elevated pressures to further understand the possible application of biomass as gasification resource in the industry.

A comparison between the raw biomass and biochar is completed with the use of several characterisation techniques which include proximate, ultimate, fibre, SEM, XRF, TGA, FTIR, surface and pore analysis. A mass loss of 83.4 % was obtained during sample preparation. While the O/C ratio is 0.66 and 0.03 and H/C ratio is 1.41 and 0.03 for biomass and biochar respectively.

Reactivity experiments are carried out in laboratory-scale high pressure fixed bed reactor for a steam partial pressure range of 0.5-20 bar. All experiments are conducted in the chemical reaction-controlled regime. The CO and CO2 products are measured using a gas analyser to determine the specific reaction rate of biochar using steam as gasification agent. While the effect of steam partial pressure on the surface area development of the char is also investigated. The kinetics are then further examined by modelling the reactivity using different kinetic models as well as several structural models.

Keywords: biochar, steam, gasification, high pressure

SESSION A1: BIO-ENERGY

Beneficiation of water hyacinth as a potential energy source by means of plasma gasification

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[2]The South African Nuclear Energy Corporation SOC, R&TD division, Pelindaba, North West

Abstract

This study aims to evaluate the feasibility of water hyacinth as a carbon fuel source in energy production. As a waste valorisation method, plasma gasification will be evaluated as a possible waste-to-energy means for hyacinth (H PlasWen). Hyacinth that grows on the Hartbeespoort dam was prepared and then characterized through the following analysis: ultimate and proximate analysis, CV and thermogravimetric analysis. Various operating parameters will be incorporated during the H PlasWen process in order to determine the optimal (best suited) parameters with regards to the feed material, desired product and current technology. The potential energy output of the H PlasWen process is then evaluated, along with the combustion and ignition characteristics of the syngas (CO/H2). The syngas yield will be predicted by simulating the reactions through the known chemical thermodynamic modelling tool, FactSage and compared to the modelled results. The results are also compared to existing feedstock that were processed using the same technology and also other technologies that were used to process the hyacinths for energy production.

Keywords: Plasma gasification, biomass characterization, syngas, waste-to-energy

Establishing a techno-economic base case for a second-generation bio-refinery: a South African perspective

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Abstract

A techno-economic base case for a biorefinery localised to South Africa was established; the biorefinery applied continuous hydrothermal liquefaction to liquid biomass waste streams. The study was presented according to two competing concepts, comprising techno-economic assessments following process modelling and simulation based on theoretical ("Base Concept") and experimental ("Proposed Concept") results, respectively. A well-recognized deterministic steady-state chemical process simulator/cost estimator was utilized for modelling the plants, calculate capital investment and operating costs, determine cash-flows and economic indicators, allowing techno-economic analysis for each concept. Positive cashflows were calculated for both concepts, with Total Capital Investment Cost and Working Capital reported at 36.03USD$mil and 5.40USD$mil, respectively, for the Base Concept. The concept's Return on Investment and Internal Rate of Return were calculated at 22% and 24%, respectively, with a Profitability Index of 4.14 – 4.52, a Payback Period of 23 years, and a Nett Cashflow of 53.25USD$mil over an assessment period of 20 years. For the Proposed Concept, Total Capital Investment Cost and Working Capital were calculated at 5.76USD$mil and 0.86USD$mil, respectively. Both the concept's Return on Investment and Internal Rate of Return were determined at 31%, with a Profitability Index of 5.45 – 5.95, a Payback Period of 30 years, and a Nett Cashflow of 11.67USD$mil over an assessment period of 20 years. Working Capital for the Proposed Concept was calculated at nearly half of that of the Base Concept. Sensitivity analyses were performed to establish the effect of economies of scale, capital investment, and plant efficiency on product unit costs. The effect of plant efficiency was illustrated.

Keywords: Hydrothermal liquefaction, Simulation, Aspen Plus, Biorefinery, Waste treatment

SESSION A2: TECHNO-ECONOMICS/LCA

Techno-economic analysis of integrated first and second generation biorefinery scenarios annexed to a typical sugar mill for bioethanol production

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Abstract

Bioethanol is proven as a clean alternative vehicle fuel, with a lower environmental impact and sugarcane has been demonstrated as an important crop for bioethanol production. Processing sugarcane allows sugarcane industries to convert first generation (1G) feedstock (molasses) and second generation (2G) feedstock (sugarcane bagasse, leaves and tops) (2G) to valuables bioproduct i.e ethanol. Although ethanol production from 1G feedstock are well established, 2G feedstock is not well developed yet. One of the solutions to improving ethanol production from sugarcane and possibly reducing the ethanol selling price, is to combine first and second-generation processes. Higher ethanol yield, improve fermentation processes and consequently reduce total capital and operating costs per unit of produced ethanol, is expected from integrated 1G2G biorefinery. The purpose of this project is to determine the most economic configuration of an integrated 1G2G ethanol process annexed to a typical South African sugar mill. Therefore, seven 1G2G biorefinery scenarios have been defined and simulated in Aspen Plus considering all required supplementary units. Through detailed process development, Aspen simulation and economic evaluation, the most economic option is presented. Furthermore, along with mass and heat integration, the self-energy sufficient concept is applied for the developed biorefineries to maximize the environmental benefit of the bioethanol production. The performance of biological catalysts, such as fermenting microorganisms and enzymes have a major effect on the outcome of each scenario and will also be discussed in detail.

Keywords: Bioethanol, sugar mill, first generation and second generation (1G2G), Techno-economic study.

SESSION A2: TECHNO-ECONOMICS/LCA

Techno-economic aspects of electricity generation from school biogas digesters

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Abstract

Biogas is a type of renewable energy produced from the decomposition of animal and plant wastes in the absence of oxygen. This study assesses the technical and economic aspects of electricity generation from school biogas digesters using human wastes as substrates. The study focuses on rural low-income schools with an enrolment of 300, 500, 700, 900 and 1100 learners respectively, as many schools in of South Africa have such enrolments. Different types of digesters were analysed and the most suitable for this study was found to be the fixed dome digester. The designed digesters have volumes of 4m3, 7m3, 9m3, 12m3 and 14m3 with profitability values of 35%, 53 %, 56%, 58%, and 59%, respectively. The payback period values are 2.6 years, 1.9 years, 1.8 years, 1.7 years and 1.6 years respectively. The research is important because it will not only provide energy for all rural low-income schools, but also help reduce environmental pollution and help the schools to generate some income from selling the biogas.

Keywords: Biogas technology, techno-economic analysis, human waste

SESSION A2: TECHNO-ECONOMICS/LCA

Economic feasibility of energy improvement in a typical sugar mill towards sustainable integrated biorefinery development

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Abstract

The South African sugar industry is currently facing an economic downturn due to various factors, majorly including low sugar prices in the global market. Sugar industries worldwide are shifting to integrated biorefineries to diversify the product portfolio towards future economic sustainability. The main driver for this new paradigm is the availability of non-food biomass in the sugar industry including bagasse and trash, which have recently gained increasing attention as cheap feedstock for biorefineries. However, most South African sugar mills burnt the bagasse in inefficient boilers to meet heating demands of the plant and thus, require improvement in the energy efficiency to release bagasse for biorefineries, which comes at a cost to the industry. This work assesses the integration of cost-effective and energy-efficient technologies including organic Rankine cycle (ORC) and absorption heat pump (AHP) into existing sugar mills to improve their energy efficiency and liberate bagasse for valorisation. These integrations were based on the thermodynamic assessment of the most inefficient unit of a typical sugar mill - the cogeneration system - using exergy analysis. Also, the economic feasibility of these integrations was assessed using Aspen® Plus simulation results. Bagasse savings of up to 2100 tons per year were realised for 250 ton of cane per hour capacity plant. The results also show the economic feasibility of the integration processes with payback periods of 6.3 - 8.3 years. The study provides the basis for further discussions around trade-offs between energy improvement and economics in the sugar industries towards the emerging sugarcane biorefinery.

Keywords: Energy efficiency improvement, Economic assessment, Absorption heat pump, Organic Rankine cycle, Sustainable biorefinery

SESSION A3: SOLAR ENERGY

Qualitative Electroluminescence imaging for Quality Control of Photovoltaic Modules

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Abstract

Electroluminescence (EL) imaging has been utilised in qualitative characterisation of photovoltaic (PV) devices since 2005. It has also been utilised quantitatively by different research groups more recently. This study presents the results of two different methods which combine different techniques to analyse PV modules.

The first of these methods, Electroluminescence Module Mismatch Analysis (EMMA), makes use of injection dependent EL imaging to determine a set of injection dependent factors and indicators of module quality. This set can then be utilised to grade a module and give an indication of the degree of cell 'match' within a module. This method has the potential to be used commercially with integration into pre-existing quality control systems.

The second method is aimed more at the individual cell characterisation within a PV module and then combining the individual cell characterisation to characterise a complete PV module more accurately. Due to the complexity of the current-voltage (IV) relation for individual cells and the presence of bypass diodes in commercial PV modules, the typical approach of dividing the voltage by number of cells is inappropriate and can lead to incorrect conclusions about the electrical response of a module. This study provides a method of determining each cell's electrical response using a combination of the dark IV response of the entire module and the injection dependent EL imaging. This method makes use of equipment that is readily available in commercial facilities as well as regular PV characterization laboratories.

Keywords: Electroluminescence, Photovoltaic, injection dependent, bypass diodes

SESSION A3: SOLAR ENERGY

Effects of varying load on Thermal Infrared Imaging of p-Si PV modules

M. Vumbugwa, J.L. Crozier McCleland, E.E. van Dyk and F.J. Vorster

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Abstract

Thermal Infrared (TIR) imaging of Photovoltaic (PV) modules is an extensively used technique applied for quick quality checks in PV plants. It identifies underperforming cells, as abnormally hot cells, on PV modules operating under steady meteorological conditions, but under dynamic operational conditions the cells can behave differently. In direct coupled stand-alone PV systems, the load dictates the operating point and thus the operational power that can be supplied by PV modules. PV system inverters ensure continual supply of maximum power to the load by constantly tracking the maximum power point (MPP) of PV modules under different operational conditions, hence the need to understand the behaviour of thermal signatures when the electrical load changes.

Varying the electrical load on polycrystalline silicon (p-Si) PV modules affects the operational point of individual cells, causing current mismatch in cell strings containing defective cells, thus forcing some damaged cells to operate and appear as good cells on TIR imaging.

TIR images captured closer to short circuit current (Isc) showed critically damaged cells (≥20% cell disconnected) that were identified through Electroluminescence imaging and were 25 °C hotter than when imaged closer to open circuit voltage (Voc). At low load more damaged cells become abnormally hot than under high load conditions when minorly damaged cells (<10% cell disconnected) behave as good cells. The effectiveness of TIR imaging depends on operating conditions and can mislead decisions on PV module maintenance. This work gives valuable information in TIR imaging and can improve maintenance systems of PV modules.

Keywords: Operational conditions, damage, thermal signature

Potential Induced Degradation (PID) cell mismatch analysis in multi crystalline Photovoltaic modules.

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Abstract

Potential Induced Degradation (PID) is a major long-term reliability issue in PV Photovoltaics (PV) plants, which is caused when a module is under high voltage stress causing leakage current to flow between the cells and the frame/earthing. PID affected cells in a module are uniquely shunted, hence there is a need to investigate the extent of PID shunting on individual cell in a module. In this study, PID is induced in a module, after PID stress of 96 hours at 1000 V in a controlled environment (35 °C and < 40% RH). The Light Current-Voltage (L-IV) curves of the module are taken with the cells sequentially individually shaded and then compared to the unshaded L-IV curve. With one cell shaded, the L-IV curve should have the expected step due to the activation of the bypass diode. However, should the shaded cell be degraded, the shading will not have this impact and the "knee" does not exhibit a step. PID affected cells will thus have L-IV curves that do not have the pronounced step. The Electroluminescence (EL) image of the PID affected modules has a checkerboard pattern, where the level of PID severity can be determined per cell by taking the average EL intensity level. The worst case L-IV measurements and the EL image confirm the effect of PID shunting and subsequent cell mismatch.

Keywords: Electroluminescence; PID; Photovoltaics, mismatch.

The effect of microalgae as a binder on the characteristics of agglomerated coal fines

JA Meyer, CA Strydom, JR Bun

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Abstract

The beneficiation of coal in South Africa accounts for more than 65 Mt of coal discards annually, of which 10 Mt are classified as ultra-fines (<150 µm). These fines render major disposal problems and have negative environmental effects, such as acid mine drainage, air pollution, and spontaneous combustion. It has been estimated that South Africa currently has accumulated more than 1000 Mt of discarded coal fines. The utilization of these fines may eliminate the negative effects and offer the potential to produce a solid fuel for industrial applications such as gasification or combustion processes. The objective of this study is to agglomerate coal fines with the addition of microalgae biomass (e.g. 20%, 10%, and 5% microalgae in the coal-algae blends) and to examine the effects on its physical, chemical, and thermal behaviour. It was found that the agglomerates produced from the coal-algae blends exhibited greater compressive strengths compared to those produced from coal fines alone. The CO2 gasification reactivities of the coal and microalgal blends were evaluated using thermogravimetric analysis; and the pyrolysis product yields at 520 °C, 720 °C, and 920 °C determined using a modified Fischer Assay setup. The various char, tar, and gas fractions produced from the Fischer Assay experiments are characterised by proximate- and ultimate analyses, gas chromatography-mass spectrometry (GC-MS), simulated distillation (SimDis), and gas chromatography (GC).

Keywords: Coal fines; microalgae; agglomeration; pyrolysis; gasification

SESSION B1: BIO-ENERGY

Bio crude oil yield predictor model: Fundamental approach using energy balance

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Abstract

Rapid population growth and urbanisation, coupled with the need of improved living standards, resulted in high amount of waste generation which lead to a need of better ways of handling waste or managing thereof. Variety of wastes have been evaluated in batch or laboratory scale as potential feedstock for fuel/energy generation however data is lagging to successfully commercialise and scale up the niche waste to energy conversion processes like hydrothermal liquefaction. For scale up and commercialise of laboratory results, information like product yields prediction and heat of reaction calculations are needed. Majority of the current laboratory models contains operating conditions or biochemical composition or lump kinetics which is a breakthrough in the liquefaction field. However, they only apply at a specific temperature and reaction time and their coefficients must be determined for each set of reaction conditions of interest. Similarly, to the kinetic model, where kinetic parameters are different for each investigation performed by researchers. From the analysis of the component additivity and kinetic models, a new quantitative model is proposed for the prediction of bio-crude yield of wet waste feedstock. The new model will be tested with large numbers of experimental and published data over a wide range of temperatures (200–400°C), retention times (1–30min) and chemical composition of MSW (lipids, proteins, carbohydrates, lignin in dry basis). The proposed model will incorporate heat of reaction/heat transfer since at constant pressures energy added is assumed to equal heat of reaction. The heat of reaction can be calculated using heat of formations. The predictive capacity of the new model will be compared with component additivity and kinetic models.

Keywords: Heat of reaction, predictive model, additive component model, heat transfer, higher heating value, constant pressure

SESSION B1: BIO-ENERGY

Furfural and ethanol coproduction from sugarcane bagasse in a biorefinery annexed to a sugar mill

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Abstract

Sugarcane bagasse and harvest residues are some of the lignocellulosic waste materials with potential to produce biochemical and biofuels as an alternative to fossil based chemicals and fuels. The introduction of high efficiency boilers and green harvesting methods can result in surplus bagasse and harvest residues which would have been otherwise burnt in sugarmill boilers and in the sugarcane farms, respectively. For value addition, furfural and ethanol can be produced from the hemicellulose and cellulose components of lignocellulosic material, respectively, using a biorefinery approach. Cellulosic ethanol from lignocellulose is energy intensive and costly due to pretreatment requirements, therefore, coproduction with furfural is envisioned to result in process economics that will attract investments. Furfural can be produced using either a one-stage or two-stage process, which presents opportunities for various furfural and ethanol process configurations with potential to improve overall process economics. The objective of the study is to evaluate the impact of process configuration on energy requirements and process economics of furfural and ethanol coproduction in a biorefinery annexed to a sugarmill. Mass and energy balances of furfural and ethanol production scenarios will be generated in Aspen Plus® using bagasse experimental data and subsequently used to determine capital and operating costs followed by computation of the minimum ethanol selling price using the discount cash flow rate of return. The study will demonstrate how furfural and ethanol coproduction process configurations affect overall energy demands and process economics of an energy self-sufficient biorefinery annexed to a sugarmill.

Keywords: furfural, ethanol, lignocellulose, acid hydrolysis, yeast fermentation

SESSION B1: BIO-ENERGY

Enzymatic upgrade of phenolic components in the aqueous phase of hydrothermal liquefaction plant

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Abstract

The current industrial production of vanillin is by chemical conversion of catechol and guaiacol from fossil fuels through a number of intermediates. Hydrothermal liquefaction (HTL) of lignin biomass is a promising source of these starting materials. Aqueous phase of HTL is rich in aromatic derivatives which are in minute concentrations due to high volumes of water. Amongst the three phases of HTL the aqueous phase is deemed of little or no use. This experiment focuses on enzymatic oxidation of vanillyl alcohol to vanillin. The initial step involves the para carboxylation of guaiacol to form vanillyl alcohol through the formylation process under acidic conditions. An enzyme vanillyl alcohol oxidase (PsVAO) is a potential candidate for the conversion of vanillyl alcohol generated from the guaiacol carboxylation step to vanillin. This is achieved through the expression of Vanillyl alcohol oxidase gene (VaoA) in E. coli cells and the ultimate use of the whole cell E. coli cells for the reaction. An alternative use of cell free extract can also be employed. Conclusions will be drawn on the vanillyl alcohol yield and selectivity towards para-vanillyl alcohol. Also the vanillin yield from the enzyme reaction in the HTL lignin biomass aqueous and/or oil phases.

Keywords: Hydrothermal liquefaction, guaiacol, vanillin, vanillyl alcohol oxidase

Towards reprocessing of fine coal tailings

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Abstract

South Africa currently has 1 Billion tonnes of discard coal, with an annual increase of around 60 million tonnes. These discards contribute to the pollution of the environment and water systems and also holds possibilities for spontaneous combustion and acid mine drainage. In South Africa around 7.5 million informal households relies on energy sources such as wood, paraffin and/or coal to meet their primary energy needs. This paper introduces a process in which ultra-fine South African discard coal can be used to produce a low cost fuel product to be used in these informal households. The first phase of the process was drying discard coal, using ceramic spheres with a diameter of 3mm in a contact sorption drying process. Various samples were successfully dried from an average feed moisture of 21 wt% to a target moisture range of around 13 wt% within 2.5 minutes. The second phase of the process is using the dried coal to produce a briquette without the use of a binder. From the characterisation of the feed coal and interpreting literature of previously done work on the binderless briquetting of South African coal it is expected that a product can be produced that adheres to the industrial specifications. This product has the potential to clean up the enormous amount of discard coal in South Africa, while supplying a low cost fuel source to informal settlements and creating jobs. In doing this the risk of fires within the settlements are reduced as coal burns with a smaller flame than wood and paraffin and the deforestation caused by the people in need of this energy source could also be minimised.

Keywords: low cost, ultra-fine discard coal, contact sorption drying, binderless briquetting

SESSION B2: CLEAN COAL

CFD modelling of the coal pellets combustion in a semi-continuous coal stove

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Abstract

The use of coal for cooking and heating in a poor-design, non-vented stoves in low-income households results in indoor air pollution which causes a significant number of deaths due to respiratory infections. Research has focused on the development of both new and effective clean coal stove designs and alternative fuels with focus being on coal pellets because of their consistent and homogeneous shape. To satisfy the requirements of efficient and clean coal combustion, it is essential to understand the combustion characteristics of coal and accurately predict the combustion process. The aim of this study is to develop a computational fluid dynamics (CFD) models to assist in future improvements of the design, operation and performance of the existing semi-continuous coal combustion stove. The objectives to be fulfilled are to; develop a mathematical model that describes single coal pellet combustion, investigate the conversion rate of the single coal pellet and the cloud coal pellets in different combustion configuration and develop a CFD model for the prediction of combustion of coal pellets in a semi-continuous stove.

Keywords: CFD modelling; conversion rate; Coal Pellets; 3D pore structure, semi-continuous coal stove.

SESSION B2: CLEAN COAL

Evaluation of coal char gasification kinetics and pore development in high pressure steam and carbon dioxide

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Abstract

Almost 23% of the countries coal is used in Coal-to-Liquid (CTL) technology for the production of liquid fuels and various chemicals such as alcohols, acids and solvents. Although the first step in this conversion is the high pressure gasification of coal, only limited studies of high pressure coal gasification kinetics with CO2 (which also partake in the reduction of CO2 emissions) and specifically steam for local Highveld coals are available. In this study, inertinite-rich coal from the Highveld coalfield was used to evaluate the coal char gasification kinetics and surface development, based on micropore surface area, at high partial pressures (1-30 bar) for the applicability in modelling the coal gasification reaction. The 75-150 µm sized coal was charred at 950°C, and subsequently, gasification experiments were performed at isothermal conditions (780°C for CO2 and 740°C for steam) in the chemical-controlled regime. The reaction rate was determined from product analysis, and it was established that not only the gasification rate but also the char surface area development is affected by the reactant pressure with greater effects from 1-20 bar partial pressure. The kinetics and pore development from steam and CO2 gasification were compared and it was found that steam reacted a factor 6 faster than CO2. The intrinsic char reactivities were determined as a function of conversion, using the surface analysis results, which were performed at 0, 10, 20 and 30% conversion. The Langmuir-Hinshelwood (LH) model gave adequately predictions of the intrinsic char reactivity, while the Random Pore Model (RPM) was used for both the pore development and the increase in reaction rate that was observed during conversion, where the structural parameters increased with a partial pressure of CO2. This finding has consequences for the modelling of high pressure gasification kinetics.

Keywords: steam and CO2 gasification kinetics, intrinsic reaction rates, High partial pressures, pore development

Comparison of industrial waste products as binders in the extrusion of coal fines

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Abstract

Coal is a valuable resource that is used in various processes worldwide: electricity generation (38%), steel manufacturing (70%), cement production (69%) and fuel synthesis (19%). However, in South Africa alone approximately 10 Mtpa of ultra-fine coal is being disposed of in coal slurry dams. Alternative methods of utilising fine coal (-500µm) and ultra-fine coal (-100µm), such as coal agglomeration, should therefore be investigated. There are three types of agglomeration methods, but only extrusion pelletising and briquetting will be considered in this study. Binders are used to increase the binding characteristics of agglomerated coal. South Africa generated roughly 67 Mtpa of hazardous waste in 2017 and these wastes should consequently be investigated to determine their binding capabilities. This study is divided into 3 phases. Phase 1 is a laboratory-scale investigation where briquettes are manufactured by pressing mixtures of inertinite-rich Highveld coal and binders in a die. The five industrial wastes (binders) included a waterworks bio-sludge (A), acrylic acid containing a hydrocarbon by-product (B), pitch (C), wax emulsion (D) and recycled low-density polyethylene (E). The concentrations were varied from 5% to 15% together with a constant moisture addition of 16.7% to determine the optimal binder concentration. The compressive strength and water resistance of the briquettes were tested for comparison. Phase 2 is a pilot-scale investigation where the optimal concentrations, as determined in Phase 1, will be used to create extrudates which will be tested to determine the compressive strength, water resistance, impact resistance and durability of the various extrudates. In phase 3 these binders will be matched with the most suitable industrial processes based on the characteristics of the extrudates.

Keywords: coal, briquetting, extrusion pelletising

Prioritizing power factor in power density assessments of doubly fed induction generator alternatives

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Abstract

Doubly fed induction generators (DFIGs) are one of the most common wind turbine generators. In this paper, it is shown that evaluating DFIG alternatives like rotor-tied DFIGs and brushless doubly fed machines (BDFMs) without proper power factor considerations, can lead to inaccurate power density estimations. Finite element analysis (FEA) models of selected DFIG alternatives designed in available literature sources, are simulated as grid connected machines. The significant variations of power output with grid side power factor of these machine are highlighted. This denotes the need for more nuanced evaluation of the power density of these machines, especially when considering grid code requirements. It is therefore proposed that the power densities of DFIG alternatives be obtained at conditions within permissible grid code conditions.

Keywords: Doubly fed machines, Power factor, Power density

SESSION B3: WIND ENERGY

A Simplified Reluctance Synchronous Wind Generator

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Abstract

Both off- and onshore wind turbines are getting bigger and more popular. There is an increased search for wind generator designs that do not make use of magnets, due to the scarcity and associated costs of these magnets. Reluctance Synchronous Generators (RSGs) offers such an alternative. RSGs typically contain complex flux barriers that raises concerns about mechanical feasibility and manufacturing complexity. This paper investigates the feasibility of a simplified and robust RSG, for wind generator drive trains in the 5 MW, medium speed range, that does not make use of the typical flux barrier rotor.

A simple, salient-pole rotor structure, with an integral stator winding is investigated as a baseline wind generator. A fractional slot winding and rotor skewing is implemented to decrease the high torque ripple, to a torque ripple below 5%. A series of individually optimized design changes are made to the rotor, in an attempt to increase the low power factor.

It is surprising that, with such a simple rotor structure, a RSG is found that delivers 5 MW of power with a torque ripple lower than 5%, efficiency greater than 98% and power factor above 0.6.

Keywords: Wind Energy, Electrical Machines, Generators, Reluctance Synchronous.

SESSION B3: WIND ENERGY

Detection, statistics and clustering analysis of wind power ramps

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Abstract

The installed wind power capacity is expected to increase in the future. It is known that wind is highly variable depending on the location and prevalent weather patterns. From the perspective of grid integration, the variable and uncertain nature of wind power poses various technical and economic challenges to power system operators who must always maintain demand-supply balance. Managing wind power ramp events is one of the major challenges associated with the successful integration of wind into power system. Wind power ramp forecasting is a key strategy to help manage the impacts of increased wind power penetration by reducing the uncertainty associated with it. However, it may be challenging to accurately forecast large ramping events. When wind power forecasts are not sufficiently accurate, additional insights on ramp events prove to be helpful in making better scheduling decisions. This paper employs the swinging door algorithm to detect wind power ramp events from measured wind power data of a utility size wind farm. Thereafter, statistical analysis of key ramping features is performed to provide insights into wind power ramp events and its management. The statistical analysis provides insights such as the rate of occurrence of ramp events, the intensity of the wind power ramps and the time period, during the day or year, which has higher likelihood for wind power ramps occurring. Additionally, cluster analysis is performed on the scatterplots of key ramp features to group ramps into clusters that share common characteristics.

Keywords: Wind energy, ramp event, detection algorithms, statistical analysis, clustering analysis

Power Curve Modelling Methodologies to Accurately Represent Wind Turbine Power Ramps

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Abstract

Wind turbine power curves depict the relationship between wind speed and power generated. Accurate modelling of power curves ensure accuracy in planning and catering for requirements of wind energy integration to the grid. Although a great deal of work has been done validating the ability of power curves to model mean power generated, their ability to model wind power ramps at various time scales is an area requiring further research. Thereby a set of power curves are derived from measured wind speed and power data for a wind farm in South Africa, using commonly employed power curve derivation methodologies. These power curves are used to model a set of 10-min, hourly and 3-hourly time series. To determine which derivation methodology performs best in modelling ramps, a comparative analysis was conducted between the measured and modelled time series across the time scales considered. This paper accordingly shows that several techniques commonly used to derive power curves result in functions that exaggerate the ramp statistics when used to model time series. The paper further goes on to show the influence of the time step under consideration on this exaggeration. The paper concludes by presenting the best performing power curve for the accurate representation of ramp statistics.

Keywords: Power Curves, Wind Power Ramps, Wind Energy Modelling, Ramp Statistics, Wind Turbines

The effect of co-liquefaction of organic solid waste with activated sewage sludge on hydrochar yield and quality

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Abstract

The past century has seen rapid global economic and technological development as well as a steep increase in global population. With this development a huge increase in waste and emissions has taken place. Only in recent years has there been a focus on how to deal with growing emissions from waste. Organic waste is generally landfilled, and it is estimated by the CSIR that organic waste that is landfilled costs South Africa roughly R10 billion each year. In this paper, hydrothermal liquefaction is used to convert the organic fraction of landfilled waste to marketable products like bio-oil and hydro-char. Sewage sludge was used as solvent in the HTL process which negates the use of fresh water for the process and also acts as a sterilisation and treatment step to recovery cleaned water from sewage sludge. The effect of co-liquefaction of with varying loadings of organic waste in sewage sludge was investigated on the yield and quality of hydro-char as main product was investigated. Early experiments have shown a typical product yields of 30% biochar and 10% bio-oil. Qualitative analysis are still to be done to determine the quality of the products.

Keywords: Hydrothermal Liquefaction, waste solution, hydrochar

SESSION C1: BIO-ENERGY

Catalytic upgrading of industrial lignin to improve bio-oil properties for renewable fuel production

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Abstract

Fossil fuels, the world's main source of energy for many decades are being depleted and a major contributor to environmental pollution and greenhouse gas emissions. It is therefore urgent that alternative energy sources are found such as liquid biofuels that could be blended with gasoline and diesel to ease the pressure on fossil fuel resources. Non-edible lignocellulosic biomass offers great potential and is a promising solution for the ongoing food vs energy debate and environmental concerns accompanying the use of fossil fuels.

The production of renewable fuel from lignin is a promising option for the future, given that processes are developed that will ensure effective energy conversion. However the complex structure of lignocellulose and the high cost associated with lignin extraction, lignin conversion and bio-oil upgrading renders lignin-based biofuels more expensive to produce compared to petroleum fuel. Therefore, research is necessary to lower the cost of a lignin-based refinery to improve the quality of the produced bio-oil for further upgrading to biofuel.

In this study the effect of feedstock fractionation, reaction parameters, and solvents on the properties of bio-crude produced through hydrothermal liquefaction from the lignosulphonate – rich feedstock are investigated. This is accomplished by fractionating the lignin in the feedstock with hexane, tetrahydrofuran, acetone, ethanol and methanol. Hydrothermal liquefaction will be used to investigate the effect of temperature (240˚C, 260˚C, 280˚C, 300˚C and 320˚C), residence time (20 min, 40 min, 60 min, 80 min, and 100 min), catalyst loading (1 wt%, 2 wt%, 3 wt%, 4 wt%, and 6 wt%) and different solvents (ethanol, methane, tetrahydrofuran and dioxane) on the properties of bio-oil produced from the lignin-rich feedstock.

The outcome of this study throws light on the effect of feedstock quality, reaction conditions and solvents used during hydrothermal liquefaction on the composition and quality of the produced bio-oil to be upgraded to biofuel. This information assists in decisions to select conditions to produce bio-oil that could be upgraded more economically to biofuel.

Keywords: Hydrothermal liquefaction; catalytic upgrading; lignin; bio-oil quality

SESSION C1: BIO-ENERGY

Increasing the phenolic content of the aqueous phase from hydrothermal liquefaction for ease of downstream recovery

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Abstract

Many studies have investigated the concentration of phenolic components formed during hydrothermal liquefaction (HTL) in the organic phase. However, phenolic components could more easily be recovered from the aqueous phase through relatively inexpensive, existing industrial methods such as adsorption. However, the effect on HTL operating parameters that would maximise the concentration of phenolic components in the aqueous phase has not yet been explored in detail. In this study, sugarcane bagasse was used as feedstock for HTL. Experiments were carried out in a batch reactor at varying operating conditions to investigate the effect of reaction temperature (280 – 320 °C), heating rate (2.5 – 10 °C/min), retention time (15 – 45 min.), and reaction atmospheres (N2, CO2 and H2) on aqueous phase yield and composition during HTL of sugarcane bagasse at a solids loading of 14.2 wt. % and a constant reactor filling volume of 50%. Design of Experiments with a 3-level factorial design was used to determine main as well as interaction effects of all variables investigated. Aqueous phase yield, total phenol content, concentration of selected phenolic monomers, monomeric sugars and organic acids and total nitrogen contents were determined as response variables. Alizarin yellow (an azo dye) was also found to be present in the aqueous phase produced during HTL under these conditions. Monomeric phenolic components of economic value identified and quantified using HPLC were guaiacol, resorcinol, catechol, syringol, and 4-nitrophenol. ANOVA statistical analysis showed that the heating rate and temperature affects the degree of depolymerisation of lignin present in the feedstock causing an increase in monomeric phenol content as temperature and heating rate increases. Higher heating rates lead to more rapid decomposition of the lignin structure resulting in higher monomeric phenol concentration and lower lignin fraction content in the aqueous phase. This is ascribed to the mechanism of degradation and repolymerisation under the different reaction conditions investigated. Although the yield of phenolic components was not significantly affect by any of the parameters investigated, the concentration of phenolic components in the aqueous phase was increased compared to phenolics in the bio-oil phase with an increase in heating rate and temperature during HTL. A maximum of 4 200 mg/L total phenol, 441 mg/L guaiacol, 192 mg/L resorcinol, 268 mg/L cathecol, 515 mg/L syringol and 310 mg/L 4-nitrophenol where obtained at 300 °C, 30 min, 4 °C/min, and in a N2 atmosphere. At these concentrations, a market value of R17,000/L could be recovered from the aqueous phase. Higher concentrations of valuable components in water is generally easier to recover than lower concentrations. This work has shown that the concentration of individual phenolic components could be increased, which would lead to easier and more cost-effective downstream separation.

Keywords: Hydrothermal liquefaction, aqueous phase, sugarcane bagasse, phenolic compounds

SESSION C1: BIO-ENERGY

Metallurgical coke substitute derived from torrefied woodchips depolymerized by wet oxidation

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Abstract

The metallurgical industry generates a vast amount of CO2 due to the use of fossil fuels as fuel or as reductant. The production of metallurgical coke from biomass can be advantageous due to biomass's CO2 neutrality. This will result in a significant reduction in coal related CO2 emissions. This study seeks to compare the performance characteristics (CO2 reactivity, mechanical strength, economics) of a laboratory prepared metallurgical coke substitute derived from the depolymerisation of torrefied woodchips having a low ash content (<4% ash) with a commercial coke (<15% ash content) derived from washed caking coal (<1.4g/cm3) from the Waterberg Coalfield. To improve the fuel properties of the biomass, the wood chips were exposed to a continuous torrefaction process at 280 °C in a rotary kiln. To decrease deficiencies in the torrefied biochar, it was pre-treated with a wet oxidation process using hydrogen peroxide as oxidising agent at 5, 15 and 30 vol %. The treated biochar was characterised using proximate and ultimate analysis, calorific value, free-swelling index, Giesler fluidity and dilatometry. A substitute coke was produced via thermal treatment at 1000 °C where after the sample was characterised using coke strength after reaction (CSR) and coke hot strength (CSI) in order to compare the properties to those of a commercial coke.

Keywords: Metallurgical coke, wet oxidation, CO2 emissions, biomass fuels, coke substitute.

SESSION C2: TECHNO-ECONOMICS/LCA

Hydrogen production from renewable sources: An environmental and techno-economic assessment

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Abstract

Renewable hydrogen is expected to make a substantial contribution in future to a sustainable society both as fuel and raw material, but this is typically substantially more expensive to produce than fossil-fuel-based hydrogen. However, considering the need for hydrogen to be a sustainable source of energy due to the global shift towards bio-economy, its production from renewable sources will be essential. The main objective of this study is to compare renewable hydrogen production technologies based on costs, environmental impact and maturity, and to propose the most viable technology for the production of renewable hydrogen. Renewable sources explored are biomass and water. Biomass can be processed by biological conversions or in thermochemical processes such as gasification, pyrolysis and combustion. Biological conversions explored are dark and photofermentation, and direct and indirect biphotolysis. The biological route is cleaner as it does not emit gases compared to the thermochemical, however, it is limited by low hydrogen yield. On the other hand, water can be split into hydrogen and oxygen using electrolysis and thermochemical splitting. The highly energy-intensive electrolysis process is powered by wind and solar, which are renewable, while the thermochemical splitting process uses the concentrated solar power to split water. This study provides a critical analysis of hydrogen production technologies, offering a valuable perspective to the green energy research field.

Keywords: Biomass, Electrolysis, Green hydrogen, Renewable energy, Water splitting

SESSION C2: TECHNO-ECONOMICS/LCA

Bio-energy from waste: Heat recovery opportunities in sustainable livestock waste management

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Abstract

Livestock waste management is a global concern as it can contribute to pollution, global warming and other environmental and social challenges. However, it has been noted that livestock waste can be value-added and turned into a resource that can benefit the farmers and minimise some of the environmental challenges. Heat recovery from biodegradation is not the conventional method of obtaining bio-energy from waste, however, it stands to benefit farmers in many aspects were heat is needed such as greenhouses, hotbeds and value addition of crops. Therefore, the main objective of this study is to present the current and developing heat recovery technologies for sustainable livestock management. The integration of the heat recovery of biodegraded material can provide much-needed heat and bio-fertiliser for on-farm processes simultaneously. In addition, it is accessible at all levels of farming including the small scale farmer.

Key words: heat-recovery, bio-energy, waste-management,

SESSION C2: TECHNO-ECONOMICS/LCA

Comparative Evaluation of the Power to Methanol Process Configurations

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Abstract

This paper compares different power to methanol process configurations with detailed focus on electrolyser(s), CO2 capture, reactor (s) and methanol purification configurations. Seven different configurations based on direct CO2 hydrogenation and CO2 and H2O co-electrolysis derived syngas were synthesized, analysed and optimized. High temperature solid oxide electrolyser(s) is used for hydrogen and syngas generation. Fixed bed reactor(s) is used for methanol synthesis. The aim of the paper is to give detailed comparison of the process layout under similar conditions and select the best performing process configuration considering techno-economics, and energy efficiency. Aspen Plus V8.0 is used for flowsheet modelling and interfaced with Excel for techno-economic optimization. The system architectures considered are the open loop systems where methanol is produced at 100 kton/annum and sold to market as the final purified product. The paper further discusses the composition and corresponding conditions which improve the energy efficiency and reduce overall process cost and their bearing potential. Following from this, the performance scenarios under which the best configuration becomes more techno-economically attractive are established as targets for further optimization requirements.

Key words: Power to Methanol system configurations, process design, process integration, High temperature solid oxide electrolyser, techno-economics.

SESSION C2: TECHNO-ECONOMICS/LCA

Novel Sterilisation Technology for High Bioburden Feedstocks in Biological Conversion Processes

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Abstract

Sterilisation is a critical step in most bioconversion processes. It helps to reduce and in some instances eradicate the bioburden of the raw material. Biological processes are often conducted as monoseptic cultures and, thus, sensitive to intruding contaminants entering the bioreactor as part of the feed. Industrial feedstocks such as paper sludge, furfural residuals, and other biological waste contain well-hidden microorganism concealed by the structure of the biomass. The proposed technology for sterilisation of such materials, makes use of a ribbon blender to force the raw material in opposite directions. The abrasive nature of direct steam further assists in disrupting the three-dimensional structure of the biomass, thus, leaving the microorganism exposed and easy to kill by thermal death. An additional feature provides sterilise passage by serving as an interface unit, thus, preventing the exposure to contaminating agents when moving the treated product from one unit operation to another. Processes that would greatly benefit from such technology include fed-batch cultures that require continues feeding of sterile product over an extended period of time. These processes may run for days on end and may suffer huge financial losses if contaminates enters either through the feed or by means of reintroduction. Stellenbosch University is planning to use this technology in their paper sludge to ethanol demonstration plant.

Keywords: Sterilisation, Bioburden, Ribbon Blender, Ethanol

Reanalysis of power system operating reserves requirements given the increasing uptake of variable renewable energy sources

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Abstract

Over the last decade there has been a significant transformation in the electricity generation sector across the world, with the aim of reducing the environmental impact of electricity generation. Variable renewable energy (VRE) sources such as wind and solar have proven to be particularly popular in mitigating these environmental impacts and in the ten years from 2009 to 2018 the worldwide total installed capacity of wind power and solar power grew from 159 GW and 23 GW to 592 GW and 509 GW, respectively. Increasing the penetration of VRE in the electricity generation mix will increase generation variability and uncertainty and can potentially introduce various technical challenges regarding the reliability of the power system network. Generation and demand must be in balance at all times for network reliability. Reliability can be analysed as adequacy – the static analysis indicating that generation capacity exist to cover electricity demand at all times. Operating reserves on the network are used to insure system adequacy during periods of imbalance and the current operating reserve requirements are likely not adequate to accommodate the increase in variability as a result of increased VRE generation. Increasing operating reserves however, comes at an additional operating cost and a new methodology will be developed to optimally quantify operating reserve requirements for a power system network with higher VRE penetration. The proposed reserve requirement methodology could be used for network planning purposes as well as network reliability optimisations for current power systems.

Keywords: operating reserves, reserve requirements, renewable energy variability,

increased variable generation

SESSION C3: ELECTRICITY GRID

A Review of Power System Flexibility Metrics

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Abstract

Generation expansion planning entails finding the optimal long-term expansion plan that satisfies economic and technical constraints for building new generation plants. Loss of load probability and expected unsupplied energy are traditional adequacy planning techniques, which are used for traditional generation plants where flexibility is already provided for. The problem with loss of load probability is that the only condition under which demand will not be met is when the demand exceeds the available capacity. Additionally, loss of load probability does not take flexibility into account. The intermittent nature of wind and solar resources makes it impossible to rely on the full rated capacity of a variable renewable energy plant for capacity planning and adequacy studies. It is important to note that a significant transition in the generation mix has occurred with the influx of variable renewable energy. Therefore, it is important to adjust the generation expansion planning models used in response to this transformation. This paper includes a comprehensive review of different system characteristics that influence the ability to provide flexibility. Also included is a review of the different flexibility planning metrics which focus on evaluating systems' and resources' ability to provide flexibility. The various generation expansion planning techniques, which are used to determine the generation mix of power plants, as well as the emerging challenges that variable renewable energy presents to generation expansion planning, are also highlighted. In particular, the generation expansion planning techniques used for the inclusion of additional variabilities and uncertainties in the planning process are discussed.

Keywords: Generation Expansion Planning, Flexibility Metrics, Power System Planning, Variable Generation Integration, Reliability Metrics

SESSION C3: ELECTRICITY GRID

Reducing the impact of embedded generation through autonomous inverters with grid support functionality

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Abstract

Embedded generation (EG) installations on distribution networks, mostly in the form of solar photo-voltaic (PV) systems, are increasing rapidly within South African municipalities. This is mainly due to the attractive payback periods using traditional electricity tariff structures. Increased load shedding is further encouraging customers to self-generate in combination with battery solutions.

The majority of these EG systems are oversized for the customers' baseload and thus grid feedback of electricity occurs. Such feedback into the distribution network can impact the voltage supplied to customers sharing the same distribution feeder as the EG system. Besides the impact on the supply voltage, this feedback might also have various other technical impacts on the municipal infrastructure.

Autonomous inverter technology with various specially developed grid support functions have successfully been implemented abroad to manage some of the above-mentioned impacts. An example of this is the ongoing partnership between the USA-based National Renewable Energy Laboratory (NREL) and the Hawaiian Electric Company, where distributed PV systems have 50%-80% penetration on various islands in Hawaii.

With increased penetration of EG installations on South Africa's distribution networks there is value in investigating how the impact of such installations can be managed through the use of similar autonomous grid-support inverters. This paper will provide an overview of the potential impacts of distribution network connected EG systems; review international experiences with the use of autonomous grid support inverters, and explore the advantages and disadvantages of this technology in managing the impact of EG on distribution network feeders.

Keywords: Embedded Generation; Distribution Networks; Inverters;

SESSION C3: ELECTRICITY GRID

Smart Inverters in LV networks: A Review of International Grid Code Standards and Opportunities for South Africa

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Abstract

Over the past few decades, the percentage of grid-interconnected distributed energy sources (DERs) has increased significantly. Even higher percentages are expected in the future as most countries have put policies, energy resource plans and incentives in place towards the adoption of more renewable energy. However, it is not so simple to progress towards a larger penetration of DERs, as there are technical challenges associated that threaten the existing distribution network's stability, reliability and power quality. Smart inverters can be used to address grid integration issues such as voltage or frequency imbalances, disconnection from the grid and over-generation through dynamic and central operation control. Due to the grid support provided by smart inverters, various countries have redefined grid codes motivated by the need to optimize distributed generation (DG) utilization while ensuring system stability. This paper reviews existing grid codes and related standards in leading countries and states with high penetration of DG, specifically Germany, California and Hawaii, within the context of advanced inverter functionality. The findings from the international guidelines are contrasted with the existing standards in South Africa to identify areas where changes are needed. The results show that South Africa would benefit from having a communication protocol, similar to IEEE 2030.5, as well as defined voltage and frequency regulation functions, similar to those stated in California Rule21 and Hawaii Rule14H. The standards need to be modified to include smart inverter requirements that are applicable for all DER sizes and types, including solar, wind, energy storage and smart loads.

Keywords: smart inverter, low-voltage distribution network, grid code standards, renewable energy integration, and penetration

Anaerobic digestion of paper sludge stillage for biomethane production

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Abstract

The paper and pulp industry is currently undergoing a shift from conventional waste management treatment such as landfilling and incineration to environmental friendlier techniques due to the enormous volume of waste generation and the stringent regulations associated with paper sludge waste management. Fermentation to ethanol is an attractive industrial technology for paper sludge disposal, while also offering stillage as a by-product, for possible conversion to biogas via anaerobic digestion. Paper sludge stillage can serve as an excellent feedstock for biogas production due to the high concentration of organic matter in the fermented residue. The current study aimed at the evaluation of anaerobic digestion of paper sludge stillage for biomethane production and the reduction of chemical oxygen demand.

Biomethane potential experiment on the paper sludge stillage was conducted using the Automatic Methane Potential Test System (AMPTS) at 10% solid loading, 37°C, and 50°C for the mesophilic and thermophilic mode respectively.

The preliminary results showed the cumulative biogas volume of 4441.3ml and 3403.33 ml for the mesophilic and thermophilic mode, respectively. The specific methane yield of 506.88 mL/gVs was obtained from the mesophilic mode as against 456.13 mL/gVs for the thermophilic mode corresponding to 11.12 % percentage increase on the methane yield. However, the thermophilic anaerobic digestion exhibited a higher chemical oxygen reduction (70.93%) at a shorter digestion retention time of 16 days compared to 65.30% at 25 days under the mesophilic conditions. The obtained results can be used to improve the performance of AD in the treatment of paper sludge stillage.

Keywords: Anaerobic digestion, paper sludge, biomethane potential, thermophilic, mesophilic, chemical oxygen demand.

SESSION D1: BIO-ENERGY

Anaerobic digestion of waste sludge originating from a recirculating aquaculture system

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Abstract

Recirculation aquaculture systems (RAS) are considered as sustainable and environmental friendly aquaculture systems capable of meeting the growing demand of seafood for human consumption. However, RAS produces large quantities of waste sludge from uneaten feed and fish faecal matter, which needs to be removed from the recirculating water, and treated to prevent adverse environmental impacts. Anaerobic digestion (AD) has been considered as an alternative method to stabilize the amount of organic waste in the environment before their disposal, with the simultaneous production of bio-methane that can serve as a source of energy within RAS. However, there are some drawbacks in mono-digestion process of fish waste such as process inhibition, unbalanced nutrients content, and low methane yields.

The main aim of this study is to optimize the biomethane production from fish sludge originating from RAS using anaerobic co-digestion. An experimental mixture design was used in order to find the optimal combination of substrates that maximize the specific methane yield and methane production rate. The bench experiment was performed by using the automatic methane potential test system II (AMPTS II) to determine the suitability and bio-digestibility of different organic substrates and also evaluate the potential methane production. Pilot-scale experiments will be conducted in order to validate the optimum results obtained at the bench scale. This study will demonstrate if the co-digestion of fish waste sludge with co-substrates (food waste and fruits & vegetable waste) produce better methane yield than individual digestion. Biomethane will be generated which can serve as a source of energy to cover the RAS energy demands.

Key words: Fish waste, anaerobic digestion, BMP, mixture design

SESSION D1: BIO-ENERGY

Fermentation of non-detoxified hardwood spent sulphite liquor using robust yeast strains and fed-batch strategy

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Abstract

Hardwood spent sulphite liquor (HW-SSL) from the paper pulping industry is a potential substrate for bio-ethanol production due to wide availability and high concentration of monomeric sugars (100+ g/L in concentrated streams). To achieve effective fermentation of this substrate, challenges such as low sugar content at dilution, low xylose consumption and high inhibitor concentrations need to be addressed. The best ways to mitigate these shortcomings in undetoxified medium, are the utilisation of robust microorganisms with xylose-fermenting capabilities and improving fermentation strategies. Three genetically modified Saccharomyces cerevisiae strains with XI-pathway expression and inhibitor tolerance namely Cellux 4™, TP1 and TFA7 were used in batch and fed-batch shake-flask fermentation of 20%, 40% and 60% (v/v) SSL medium. Cellux 4™ achieved the highest ethanol concentration, xylose uptake rate and productivity at low SSL concentrations (20% and 40%), but this decreased drastically as SSL concentration was increased. This indicates that the advanced xylose-utilising phenotype of Cellux 4™ deteriorates with increased inhibition. TFA7 achieved the highest ethanol concentrations at 60%, proving that it is more robust than Cellux 4™. The low xylose uptake rate and productivity of TFA7 achieved at even low concentrations of SSL indicates a trade-off between inhibitor tolerance- and xylose-utilising phenotypes. The evaluation and identification of suitable microorganisms are essential in the development of industrially feasible bioethanol processes. The economic shortcomings of current fermentation processes are the major obstacles in the effort to subsidise fossil fuels with bioethanol.

Keywords: Spent sulphite liquor, Bioethanol, Saccharomyces cerevisiae, Fed-batch, xylose

SESSION D2: TECHNO-ECONOMICS/LCA

Scale-up production of bioethanol from paper sludge utilising pulp mill process water

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Abstract

The effects of climate change have generated an increased interest in environmentally friendly energy sources. Bioethanol produced from paper sludge (PS) is such an alternative and has the potential to contribute to sustainable bio-based energy generation. However, for such a process to be economically viable, the dosages of commercial enzymes, which significantly contributes to process cost, have to be minimized, while ethanol concentrations of >40 g/L are required. Furthermore, the pulp and paper mill industry consumes significant amounts of fresh water, which is a scarce resource. Therefore, this study aimed to produce a high yield bioethanol using PS wastes as substrate, in a process that minimises commercial enzyme dosages, and utilises unprocessed recycled process water from pulp mills. Three PS types virgin pulp (VP), corrugated recycle (CR) and tissue printed recycle (TPR) were fermented in 5L and 150L bioreactors using a simultaneous saccharification and fermentation process with final solids loadings for VP, CR and TPR of 18%, 27% and 33%, and enzyme dosages of 20, 11 and 15 FPU/gds, respectively. The 5L fermentations produced ethanol concentrations >40 g/L for VP and TPR, while this ethanol concentration was only achieved for TPR in the 150L bioreactors. The reduction in ethanol concentrations for 150L fermentations was attributed to fouling due to the presence of bacterial contamination. Ethanol concentrations of >40 g/L were achieved with unprocessed recycled process water and minimised enzyme dosages; these can be improved further with process optimization, especially alternative sterilization techniques to eliminate contamination.

Keywords: Paper sludge; Bioethanol; Process water; Fermentation

SESSION D2: TECHNO-ECONOMICS/LCA

High throughput bio-methane potential (BMP) as a predictor for process behaviour of commercial-scale anaerobic digesters

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Abstract

At steady-state conditions, full-scale anaerobic digestion (AD) plants generate methane-rich biogas by utilizing industrial organic wastes, e.g. livestock manure, food processing wastes and abattoir effluents. However, two major issues impact the steady operation of such plants: (1) the reliability of assessing feedstocks' methane potentials at laboratory-scale and inter-scale results transferability, and (2) the variation of feedstocks' compositions with time. The first challenge refers to laboratory-scale biomethane potential (BMP) assay tests, a standardised protocol used to estimate the methane potential (or specific methane yield, SMY) of a feedstock. This SMY data is then referred to for the design of larger AD systems. Consequently, the performance of large-scale AD systems is overestimated because of differences in process conditions of test scales. The second challenge refers to time-dependent compositional fluctuations in feedstocks, which impacts the quality and production of methane. The large AD reactor volumes (500 to 50 000m3) further complicates these issues, with apparent scale-up effects.

This project aims to assess whether a feedstock's SMY determined under standardised BMP assay conditions can be used to accurately predict the SMY and performance of full-scale AD systems. Distillery wastewater (DW), the feedstock, will be mesophilically (37oC) digested in laboratory (0.60L) and pilot (35L) AD tests. Generated SMY data will be compared between scales, including the plant scale (2200m3) to develop a predictive model factoring in scale-up effects. Preliminary experiments showed that the SMY obtained for DW in BMP tests was 153NL/kgCODfed, roughly 26% of the plant-scale SMY treating the same DW (207±45.5 NL/kgCODfed).

Keywords: Anaerobic digestion, BMP assay tests, scalability, specific methane yield, predictive model

SESSION D2: TECHNO-ECONOMICS/LCA

Applications for lignin hydrothermal liquefaction products

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Abstract

In terms of biomass valorisation through thermochemical processes, hydrothermal liquefaction (HTL) is attractive relative to other process types, based on favourable reaction conditions, elimination of feedstock drying and the use of water as reagent. Lignin either in an isolated form or as a biomass component yields a mixture of products through HTL, dependant on source and reaction conditions. Compounds include aromatics, phenols, organic acids, aldehydes, ketones, alcohols and biochar, amongst others. Some products have the potential to be employed in high value applications, following the separation of viable quantities which is a crucial factor. Here are presented some of the applications that have been identified and investigated recently, including organic acids as precursors, polyhydroxyalkanoates, battery electrodes, activated carbon, polyols, resins and flavouring.

Keywords: green, biobased, polymers, carbonization, biotransformation

Calibration of a Heliostat using a Drone

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Abstract

Heliostat calibration is time-consuming. It takes several months to calibrate the heliostat-field in a concentrated solar power (CSP) plant. Since a particular heliostat cannot be calibrated often, it has to keep its calibration accuracy for several months. Therefore, heliostats are manufactured to be very sturdy and robust, which makes the installation a lengthy process and the actual heliostat, expensive.

It may be possible to reduce the calibration time of a heliostat by using a different calibration technique. At the moment, heliostats are calibrated using a beam characterization system (BCS). This system moves the sun's reflection of a heliostat from the receiver to a calibration target below the receiver. The proposed calibration technique, researched in this project, will make use of drones to calibrate the heliostats. The camera on a drone will, effectively, replace the sun in the calibration setup. In theory, a drone will be able to calibrate a heliostat and be able to calibrate more than one heliostat at a time and can calibrate during the night. This will result in a significant faster calibration process.

A heliostat in the Helio100 field will be calibrated with the existing system and the same heliostat will then be calibrated with the drone system. The pointing accuracy that results from the two calibration systems will be compared. Preliminary tests have shown that the pointing accuracy resulting from these two systems are comparable. The paper will also discuss the practical challenges of the drone calibration system.

Keywords: CSP, calibration, heliostats, drones, BCS

SESSION D3: SOLAR ENERGY

Performance analysis of variable speed solar gas turbine configurations

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Abstract

Solar gas turbines require supplementary energy input, typically from combustion, to compensate for the variability of the solar irradiance and maintain constant operating conditions. Without the additional thermal energy, the operating points of the gas turbine components, and hence the thermal efficiency of the engine, will change unless the load is also adjusted. This is due to the design of the gas turbine core, in which the compressor and turbine components are connected by a common shaft, and synchronization of the generator speed with the electricity grid, both of which adversely affect the off-design performance of the engine. This paper evaluates the extent to which the low-DNI performance of a solar gas turbine can be improved through modification to enable variable speed of one or more of the engine components. A plant simulation model is developed by modelling a solar receiver, a heliostat field and a gas turbine generator set and used to compare the performance of three alternative generator set configurations to that of a reference case, namely the Solar Upscale Gas Turbine (SOLUGAS) system developed by Abengoa. All three cases show increased net power output and reduced fuel consumption compared to the reference. It is shown that the case using power electronics can produce the same power output as the reference using 9.28 % less fuel. The fuel savings are accompanied by a reduction in air mass flow rate, which may allow for the use of a smaller solar receiver. This possibility is being explored.

Keywords: solar gas turbine, variable speed, off-design, low-DNI

Heliostat soiling studies and photo/image-analysis

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Abstract

Current investigative efforts in the concentrating solar thermal (CST) energy field are focused on trying to integrate solar thermal heat energy into energy-intensive industries. An example of this is the PRÉMA project, looking to pre-heat manganese ore using solar thermal heat energy, thus reducing the smelting process' total carbon footprint. This application of CST technology has not been attempted before partly because of the high levels of industrial dust pollution expected in an industrialised zone. High dust loadings directly affect the heliostat fields optical performance and therefore, the CST plant's solar-to-heat energy conversion efficiency, implying the need to investigate the feasibility of siting a CST plant in an industrialised zone. This paper seeks first to highlight the importance and progress of heliostat soiling studies up to now, then describing photo/image analysis methods used by the authors in a novel setup to that end. Initial results from this long term study will also be reported.

Keywords: Energy-intensive industry, Solar thermal process heat, Heliostat soiling, Reflectance.

SESSION E1: BIO-ENERGY

Evaluation of the kinetics of cellulase recycling on bioethanol production from paper sludge

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Abstract

The cost of enzymes used for second generation bioethanol production, remains to be one of the main economic challenges. Enzyme recycling is a natural way of reducing enzyme dosage and thus, the cost of the overall process.

The feasibility of recycling both liquid and solid-bound enzymes by physical separation was investigated. Paper sludge fermentation was conducted over a system of three sequential rounds whiles recycling enzymes in both phases. Kinetic model predictions of cellulase activity were used to minimize the supplementation of fresh enzyme in the recycling system.

Approximately 48% and 42% of the initial Cellic CTec 3 activity was conserved in both the liquid (supernatant) and solid (broth) phases respectively after 72 hours of fermentation. An ANOVA analysis (confidence interval of 95%) indicated no significant variation in ethanol yields determined from recycling both liquid and solid-bound enzymes whiles enabling up to 35% savings on enzyme dosage. The development of kinetic models for residual cellulase activity predictions accounted for the exponential decay of enzyme activity over time as well as the decline in enzymatic hydrolysis of the paper sludge.

Employing enzyme recycling has the potential of improving the economic feasibility of second generation bioethanol production and thus, making it a more viable substitute to fossil fuels.

Keywords: Paper sludge, Cellulase recycling, Kinetic model, Enzyme activity decay, Cellulosic bioethanol

SESSION E1: BIO-ENERGY

Investigating the preferred feedstock for renewable aviation biofuel production

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Abstract

A recognition of the associated impacts of the aviation industry in contributing to unfavourable environment outcomes via greenhouse gas emissions has necessitated a renewed interest in the production of bioethanol as a sustainable aviation fuel. Crucially however, such biofuel production is typically characterised by high production cost which has so far limited its widespread acceptability. In an attempt to significantly reduce the biofuel production cost, the present study seeks to leverage the existing PetroSA facility, via the utilisation of existing process equipment as an approach to limit capital expenditure. Specifically therefore, the study investigates several biofuel production scenarios in other to facilitate the identification of the preferred pathway that presents the lowest-possible cost of supplying the desired 300ML/year of ethanol to PetroSA in Mossel Bay, South Africa. In this study, our methodology incorporates techno-economic assessments of biochemical and thermochemical conversion strategies for biofuel production using unconventional feedstock such as paper sludge, lignocellulose waste, invasive alien plants, molasses etc. It is anticipated that a successful completion of this study will facilitate the identification of the technically preferred and economically most favourably biofuel production pathway. The results obtained from this study will therefore be vital in aiding future decision making regarding the preferred feedstock, configuration and production pathway for sustainable bioethanol generation, and thus further encourage the paradigm shift to a greener aviation sector, for the benefit of all South Africans.

Keywords: PetroSA; Bioethanol; Techno-economic assessment; Greener aviation sector

SESSION E1: BIO-ENERGY

Steps toward the standardisation of the separation of aqueous phase value-added chemicals from the hydrothermal liquefaction of waste lignin

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Abstract

Hydrothermal liquefaction is gaining attention due to the vast advantages and products it offers over other thermal processing options. Due to the ineffectiveness of the HTL process, however, other streams (such as the aqueous phase) has to be investigated to improve the economic prospects of the process. It is well known that biochar, bio-oil, biogas, and an aqueous phase are obtained as products during the HTL process. Biochar can be used as soil amendments, catalysts, etc. Bio-oil can be upgraded by removing oxygen and hydrogen groups by hydrotreating for it to be used as in-line fuel. Biogas contains a predominant amount of CO2 and comprises of less than 10wt% of the products, and is therefore mostly negligible. The aqueous phase offers an interesting avenue in which organic (phenolics, n-containing products) and inorganic (N, P, K) material can be extracted to enhance the HTL process. However, in utilising these organic and inorganic materials the effectiveness of the extraction solvent is of utmost importance as this determines the overall effectiveness of the product utilisation downstream. It is therefore necessary to investigate the effect extraction solvents have on the distribution of organic and inorganic materials to ascertain an optimal strategy for the separation of products to produce a cost effective and efficient process. In this study the aqueous phase from waste lignin (sodium lignosulphonate) was investigated and the influence popular solvents (acetone, DCM, hexane, and no solvent) being used had on the separation of organic and inorganic components on the distribution of products in the aqueous phase.

Keywords: Hydrothermal liquefaction, aqueous phase, waste lignin, organic materials, inorganic materials, solvent extraction

SESSION E2: CARBON CAPTURE & STORAGE

Experimentation and modelling of SO_2 absorption using spray dry scrubbing

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Abstract

South African coal-fired power stations need to comply with national and international requirements on SO2 emission standards. Most designs of SDS systems are specific to European power stations and coal characteristics. Such systems are also based on empirical and semi-empirical correlations limiting the set of design factors that may be investigated. Computational Fluid Dynamics (CFD) modelling is therefore considered to be essential in aiding the understanding of the design and operation process, to guarantee compliance with the rigorous emission standards.

An investigation was undertaken to determine the performance of a laboratory-scale spray dryer involving FGD in order to contribute to the understanding, modelling and design of an industrial process. The study consisted of a systematic experimentation programme involving the integration of evaporation, drying and SO2 absorption. The experimentation also involved the evaluation of different sorbents with relevant properties which are readily available. An important aspect of the experimentation is that process conditions (state variables) within the dryer/absorber space such as temperature, velocities, humidity, SO2 concentration were measured accurately in addition to the controlling input and output variables, such as flowrates, temperatures, concentrations, and efficiency (calculated). The parametric analysis indicated two separate drying phases in the absorber i.e. constant drying phase which accounts for high SO2 absorption and the falling rate period where dry porous particles are formed at a slower rate. The hydrodynamics within the column were explored using CFD simulation (STARCCM+). A simplistic evaporation model together with SO2 absorption were examined; the integrated model compared well with experimental data.

Keywords: Spray drying absorption, FGD, experimentation, sorbents, CFD modeling.

Characterization and adsorption rate modelling of activated carbon sorbents for carbon dioxide capture

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Abstract

An investigation was undertaken to study the CO2 and N2 adsorption, thermodynamic properties and adsorption kinetics of two different activated carbon samples to contribute to carbon dioxide capture technology using a circulating fluidized bed process. The activated carbons were derived from coal (CQ006) and coconut shells (CQ650). Sample characterization was conducted on the two dry activated carbons using various techniques including proximate and ultimate analyses and CO2 and N2 low-pressure gas adsorption (LPGA). Characterization data show that the two activated carbons, CQ650 and CQ006, are rich in fixed carbon (90.2 and 87.9 wt.%, db) and low in ash yields (4.3 and 4.3 wt.%, db); and exhibited relatively high Dubinin-Radushkevich (D-R) micropore surface areas ranging from 735 and 670 m2/g, respectively. The samples' adsorption isotherms for CO2 and N2 were acquired from a modified Micromeritics ASAP 2020 Apparatus in the pressure range, 0.05 mbar to 1.20 bar, at four different temperatures within 0 - 30 °C. For CO2 adsorption, the Dubinin-Astakhov (D-A) isotherm model showed the best agreement, whilst for the N2 adsorption the Brunauer-Emmett-Teller (BET) isotherm model showed the best agreement. A laboratory scale differential packed bed reactor (FBR) has been built and operated to measure the adsorption kinetics for the sorbent at different operating conditions. The adsorption kinetic experimental results are used to develop suitable adsorption rate models such as the pseudo first order, pseudo nth order and reaction/diffusion rate models together with the relevant parameters.

Keywords: Carbon dioxide capture, activated carbon sorbents, characterization, adsorption capacities, adsorption kinetics.

SESSION E2: CARBON CAPTURE & STORAGE

Biogas-fuelled absorption refrigeration as a means of reducing post-harvest losses in the rural fisheries of Lake Victoria

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Abstract

Fourteen percent of global food produce is lost up to but excluding the retail stage. These post-harvest losses (PHL) are particularly prevalent in the developing countries of Sub-Saharan Africa (SSA) which are characterised by poverty, food insecurity and an under-investment in infrastructure. The proposed research combines anaerobic digestion and absorption refrigeration to provide off-grid cold storage in SSA. The research focusses on the artisanal fisheries of Lake Victoria to demonstrate the utility of this technology. Modern cold storage is not accessible to fisherfolk who traditionally rely on smoking and sun drying to preserve their catch. These techniques reduce both the quality and quantity of retailed fish and contribute to the region's PHL. The anaerobic digestion of locally available organic matter like fish processing effluents, cow manure, maize stover, water hyacinth and common reed produces biogas which is a sustainable biofuel that can fuel absorption refrigeration.

The main objectives of the research are to perform a biochemical methane potential (BMP) assay of the substrates available in the Lake Victorian region and to assess the performance of a conventional aqua-ammonia absorption refrigerator converted to run on biogas as opposed to LPG. Various substrates are co-digested with different concentrations of fish effluent and ensilage is considered as a biological pre-treatment to reduce the recalcitrance of lignocellulosic substrates. The absorption refrigerator prototype is used to assess the evaporator temperature as a function of biogas and LPG flowrates. These factorial experiments inform the BMP of Lake Victorian substrates and the practicality of biogas-fuelled absorption refrigeration.

Keywords: Anaerobic Digestion, Absorption Refrigeration, Biogas

SESSION E3: WIND ENERGY

The effect of rural electrification on the adoption and use of electric appliances among rural households in the former Transkei: an overview of the Mnquma local municipality

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Abstract

Load-shedding and expensive electricity in South Africa is on inner ease. Energy security is essential to economic development across the world. Electricity is one of the most beneficial types of energy that affect rural households but in South Africa (SA) there is still less access to electricity, even the available electricity is not affordable. Mnquma Local Municipality households with electricity have more demand for utilization of electric appliances. The aim of this study is to examine the effect of rural electrification on the adoption of electric appliances among Mnquma Local Municipality rural households in the former Transkei. The study employed primary data obtained from 224 households in Mquma Local Municipality where simple random sampling technique was used from each of the three electrification stages. Probit model were used to determine the relationship between socio-economic and demographic factors of the household and the adoption of electrical appliances use in the electrification stages.

Results of Probit Model measured the effect of gender, household size and education level as statically significant for the adoption on new electrical appliances. This research suggests that electric appliances adoption has a significant effect on households' income. Probit Model predicted 36 per cent of the sample correctly. Both regression models revealed that household size as positive significant variable to adoption of electrical appliances by 1% level (0.000).

Policies must be put in place to facilitate to make affordable electric appliances that will provide households with social benefits. Appliances should be simple to use and durability should be a good choice for households that are technologically illiterate, facilitating the transition from biomass to electricity to improve energy security.

Key words: electrification stages, energy security, electric appliances, adoption, probit model.

SESSION E3: WIND ENERGY

A techno-economic evaluation of powering Madlala high school, South Africa, with solar energy

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Abstract

Abstract: The study focuses on the techno-economic assessment of powering Madlala High school, Mpumalanga province with photovoltaic energy, with the aim of determining the positive economic benefits to Madlala high school that the proposed system will provide. Madlala high school is situated in Bushbuckridge with the total enrolment of 900 learners. Eskom electricity from coal is used to supply energy to the school. The number of photovoltaic modules, inverters and solar batteries were sized. A techno-economic assessment was done to find the profitability and favourability of the photovoltaic investment project at the school, the total energy demand for the school was 15.9975 kW per month. The number of solar modules was found to be eleven, each solar module with a power rating of 360W. The inverter required by the school is 20kW-30kW grid inverter. The profitability of the investment project was 50%. The Net Present Value (NPV) was R110 654.64 and finally, the payback period was one year. It is highly recommended that the school should use solar modules for providing energy for the school in form of lighting and heating. It is further recommended that the school should build underground fixed biogas digesters to produce biogas, utilizing human excreta from learners as biogas substrate.

Keywords: techno-analysis, biogas digester, energy demand and system sizing

SESSION E3: WIND ENERGY

A techno-economical investigation of the application of floating solar PV (FPV) in South Africa

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Abstract

The solar rich South African climate has made solar energy a fast growing alternative to transit country's dependency on fossil based electricity generation to the one more dependent on renewable sources. The issue of large pieces of land used for utility scale solar PV plants has created problems of land price hikes and complaints from food security organisations as it competes with agriculture and residential development. Floating PV (FPV) solar systems are a solution to this problem as an innovative approach to harvesting solar energy on water surfaces instead of land while increasing efficiency of solar PV system. Though FPV systems are showing tremendous growth in other countries like China, India, Korea, Italy and UK, Africa still have one small plant in South Africa that was installed by a group of farmers for their agricultural purposes that has been operational since March 2019 and there is a utility scale FPV project of about 4MW installed capacity in Seychelles expected to be operational this year 2020. FPV systems can also be used as a clean and safe solution to replace the Koerberg Nuclear Power Station that is reaching its end of life in 2024. This paper will discuss the techno-economical investigation of the application of FPV in South Africa. The paper will focus on the benefits, effects and challenges of FPV, technological overview, policies and project structuring and the cost of FPV solar systems that will include the calculating of Levelized cost of electricity (LCOE) on each proposed dam.

Keywords: Floating solar PV, Levelized cost of electricity, renewable energy

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