UNIVERSITY OF ALBERTA
FUTURE ENERGY SYSTEMS

2018 FUTURE ENERGY SYSTEMS RESEARCH SYMPOSIUM

March 14, 2018 | 8th Floor, Donadeo Innovation Centre for Engineering, University of Alberta

www.futureenergysystems.ca/symposium2018

CANADA FIRST
RESEARCH EXCELLENCE FUND

THE FUTURE OF ENERGY IS HAPPENING NOW

Our future energy needs will not be met by one source, but many. Hydrocarbons, wind, solar, biomass, geothermal, hydro, nuclear, and other technologies can all contribute to a complex system that meets our society's increasing energy needs, while reducing our carbon footprint.

Future Energy Systems focuses on multidisciplinary research that develops the energy technologies of the near future, explores how these technologies can be integrated into our present-day infrastructure, and examines possible consequences for our society and the economy. It also contributes to the development of solutions for challenges presented by current energy systems, and considers the potential effects of new energy technologies.

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Welcome to our first annual Research Symposium

Future Energy Systems came to life in December of 2016 with $75 million from the Government of Canada's Canada First Research Excellence Fund (CFREF).

This investment came with obligations: in its application for CFREF funding, the University of Alberta had promised to help Canada solidify its position as a world leader in future energy research –– a pledge our university is uniquely able to make because our community includes more than 200 energy researchers from 23 departments across 10 faculties.

Over its seven years, Future Energy Systems will support more than 100 of these researchers and up to 1,000 Highly Qualified Personnel (HQP) as they conduct research across 14 themes. Our projects examine the responsible development of hydrocarbons, the improvement of environmental performance for our energy system, renewable energy technologies and the infrastructure that enables them, and the system-wide implications of change. These diverse areas of focus are inherently complex, so addressing them effectively required organization, adaptation and speed.

Our administrative team came together in April 2017, and by June projects were being launched. In October, we showcased more than forty projects at our first open house event, and today more than fifty are underway. Our diverse research group includes academics and students from the Faculties of Agricultural, Life and Environmental Sciences, Arts, Engineering, Native Studies, Science, as well as the Alberta School of Business and Campus Saint-Jean.

Today's research symposium is the first chance for many of our projects to report on substantive progress. Bearing that responsibility are our HQP –– graduate students and post-doctoral fellows who will offer 20 presentations, 12 pitches, and 70 posters representing a huge range of disciplines.

I would like to personally acknowledge the hard work of all these individuals, and the investigators providing them with guidance. As a university research initiative, Future Energy Systems' greatest legacy will be the HQP you meet today –– young experts who can spend the coming decades tackling new energy questions as our society's relationship with energy continues to evolve.

Today, I hope all members of our Future Energy Systems research community will join our external guests in exploring the breadth and depth of our program. By bringing together such a diverse group of talented individuals, we have the opportunity to break conventional barriers and seek truly innovative solutions for humanity's energy future.

Thank you for joining us at this special inaugural research symposium. I hope to see you at many more Future Energy Systems events in the years to come!

Dr. Larry Kostiuk
Director, Future Energy Systems

TIME	DESCRIPTION	SPEAKERS
8:30	Welcome and Introduction	Dr. David Turpin *President, University of Alberta* Dr. Larry Kostiuk *Director, Future Energy Systems*
9:00	Session 1: Biomass, Energy Humanities, Wind *Presentations - 5 x 10 minutes + Q & A* *Pitches - 3 x 3 minutes*	*Presentations:* Hector Vargas, Irene Onyango, Masoud Aliramezani, Mary Elizabeth Luka, Libin Liu *Pitches:* Jie Wang, Catherine Tays, Jessie Beier
10:15	Networking Break / Poster Viewing	
10:45	Session 2: Carbon Capture, Utilization & Storage, Heavy Oil - In-Situ, Heavy Oil - Non-Aqueous Recovery, Land & Water *Presentations - 5 x 10 minutes + Q & A* *Pitches - 3 x 3 minutes*	*Presentations:* Tsai-Hsing Ho, Rajan Patel, Gloria Okpala, Muhammad Arshad, Selamawit Messele *Pitches:* Kasturi Pai, Chang Gao, Stephanie Ibsen
12:00	Lunch / Poster Viewing	
13:00	University of Alberta Facilities Development & Energy Strategy	Andrew Sharman *Vice-President (Facilities & Operations), University of Alberta*
13:30	Future Energy Systems – Administration Update	Dr. Larry Kostiuk *Director, Future Energy Systems* Dr. Marija Petrovic *Assistant Director, Future Energy Systems*
14:00	Networking Break / Poster Viewing	
14:30	Session 3: Geothermal, Non-Electric Infrastructure, Solar *Presentations - 5 x 10 minutes + Q & A* *Pitches - 3 x 3 minutes*	*Presentations:* Evan Renaud, Jason Michaud, Nebiyu Kedir, Chao Wang, Bing Cao *Pitches:* Calynn Stumpf, Yajie Hao, Sheng Zeng
15:45	Networking Break / Poster Viewing	
16:15	Session 4: Grids & Storage, System Wide *Presentations - 5 x 10 minutes + Q & A* *Pitches - 3 x 3 minutes*	*Presentations:* Farzam Nejabatkhah, Daniel May, XueHai Tan, Tim Weis, Ankit Gupta *Pitches:* Balakrishnan Nagarajan, Michael Moore, Tanveer Mehedi
17:30	Reception / Poster Viewing	
18:00	Award Announcements	Dr. Larry Kostiuk *Director, Future Energy Systems* Dr. Stefan Scherer *Executive Director, Future Energy Systems*

Session 1 - Biomass, Energy Humanities, Wind

THEME OVERVIEWS

BIOMASS

We already know how to create fuels from certain types of biomass, but many other feedstocks can potentially be transformed in a similar manner. In order to identify new viable sources, we must develop more a sophisticated understanding of the technological processes that might be used to convert biomass to fuel, and assess the potential business cases for adopting certain sources that might have other economic uses, or compete with established cash crops. We can also explore the potential for tailor-made fuels for the transportation sector, developed from biological sources.

ENERGY HUMANITIES

Throughout history, human society has been profoundly changed by the integration of new energy systems. From the adoption of fire as a means of gaining warmth to industrialization reshaping settlement patterns and changing social norms, energy's impact has been far-reaching, and has required us to re-imagine the ways we interact with each other and our environment.

Employing a full spectrum of disciplines from the arts and humanities, we can try to better envision what the next iteration of this evolution will look like, and to communicate about the challenges and opportunities that lie ahead.

WIND

Wind has powered human societies for centuries, milling grain, pumping water, and driving ships around the globe. In recent years, maturing technologies have enabled the same resource to generate electricity, and contribute significantly to the energy needs of numerous countries. However, the challenges of harnessing wind remain: it is an ever-changing force, and its cycles often do not align with our demands.

Effectively integrating wind into our grids and markets requires both technologies and an economic system that can accommodate these variations in supply. Understanding the special challenges of harnessing wind power in the Canadian north will be a specific priority.

PRESENTATIONS

HECTOR VARGAS SEPULVEDA

Decreasing costs of biofuel production through co-production of value added products from alternative feedstocks (Biomass)

To offset biofuel production costs, we employed a biorefining approach that enables co-production of high value products. For example, isolation of ß-glucan from Fibar barley using Air Currents Assisted Particle Separation (ACAPS) generates a starch concentrate that is efficiently converted to ethanol (86.7 ± 3.5%). Furthermore, enzyme hydrolysis of starch concentrate is significantly more efficient compared to conventional wheat flour, producing more than 2-fold greater glucose after only 2 hours. Thus, we are examining lower enzyme loading to reduce process costs and potentially improve ethanol yields through reduced osmotic stress. In addition, we are treating seaweed with enzymes to improve process costs of existing agricultural biostimulant production. Celluclast 1.5L released 2.04 ± 0.09% glucose and 7.14 ± 0.04% mannitol, with noticeable changes in the physical characteristics of the supernatant. This highlights the promise of using enzyme hydrolysis to release agricultural biostimulants, leaving a fermentable sugar-rich feedstock.

IRENE ONYANGO

Forestry footprints associated with providing harvesting residues for a lignocellulosic biorefinery in Alberta (Biomass)

We investigate the feedstocks available from forest residues to feed a lignocellulosic biorefinery. We assume that the biorefinery would be located adjacent to one of the six existing pulp mills in Alberta. The feedstock would come from residues in the form of currently unused branches and treetops as a by-product of the pulp mill's forest harvesting. Since feedstock delivery cost will be a major factor in selecting the optimal biorefinery location,

for each of the six pulpmill locations, we identify and map the forest area that would be needed to supply a biorefinery that uses 1.8 Mt/yr of residues. The smaller this harvested area – which we refer to as the forestry footprint of the biorefinery – the lower the delivered feedstock cost. Forestry footprints vary in size depending on the inventory of standing timber within the forest stands adjacent to each location.

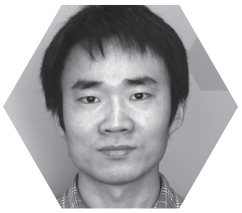
MASOUD ALIRAMEZANI
Optimizing in-use emission sensors for OME fueled CI engines (Biomass)

The high efficiency and fuel economy advantages of Diesel Compression Ignition (CI) engines make them interesting for power generation systems. However, the high NOx and particulate matter emissions present the most important challenges of using CI engines. Therefore, complex engine control strategies and after treatment systems are needed to meet stringent emission regulations. To optimize CI engines performance with biomass generated OME fuels and to minimize emissions, a robust control strategy with a reliable on-board emission measurement system is required. This project is focused on both experimental and model development for "in-use" fast emission sensors. This includes developing physics based models and validating them with the experimental setup that includes an accurate gas mixing apparatus and a reliable external emission measurement system (FTIR). The results will be used to optimize the sensitivity of NOx, O2, NH3, and HC sensors for different conditions including OME fueled CI engines.

MARY ELIZABETH LUKA
iDoc: producing meaning, generating dialogue (Energy Humanities)

Last November, iDoc began video-taping four pilot interviews with FES team leaders. iDoc was designed to provide the FES Energy Humanities team with dialogues grounded in the fourteen themes by end of 2018 that could be juxtaposed in service of assessing the social impact of current energy transitions. Unsurprisingly, most FES researchers we spoke to were passionate and articulate about their own research objectives. But the interviews clearly needed to be brought into conversation with civic actors such as artists, activists and policy makers. Fortunately, the iDoc project was designed to be flexible, and iDoc PI Sheena Wilson's SSHRC-funded project, Feminist Energy Futures, was already mapping such civic actors. So, iDoc expanded. By March 14, 50 interviews will have been recorded: a tenfold increase from the original goal. In this presentation, four HQP from iDoc discuss lessons learned so far, and invite you to be a part of it.

LIBIN LIU
Vibration signal analysis for planetary gearbox fault diagnosis (Wind)

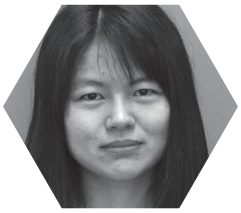


This project aims at developing vibration signal analysis methods for planetary gearbox fault diagnosis. The target is to characterize properties of vibration signals and to extract fault features in vibration signals for planetary gearbox fault diagnosis. Firstly, a planetary gear set vibration signal model with transmission path effect is developed to characterize properties of the expected vibration signals. Secondly, a copula-based time-frequency distribution (TFD) is developed for energy density representation in time-frequency domain. Thirdly, a method to extract fault-induced impulses via dimension reduction of copula-based TFD through non-negative matrix factorization is explored. Fourthly, a dependence-based feature vector is developed for planetary gearbox fault diagnosis, where the dependence is between intrinsic mode functions and raw vibration signal. Overall, the generated knowledge can generate potential benefits for operators of wind farms wherein turbines have planetary gearboxes as key components and reliability and safety of turbines are of paramount importance.

PITCHES

JIE WANG

Development of advanced processing strategies for Ethanol/ CNC co-production (Biomass)



This project uses advanced fermentation strategies to improve ethanol productivity from sugar streams recovered from partial degradation of wood pulp by cellulase. Selective enzymatic treatment was designed to efficiently recover a high value product, cellulose nanocrystals (CNC), from acid hydrolysis of enzyme-treated feedstock. In parallel, a self-cycling fermentation (SCF) approach was mimicked in shake flasks to elevate ethanol productivity. Compared with batch fermentation, SCF improves ethanol volumetric productivity (titer of ethanol produced per time) and annual ethanol productivity (amount of ethanol produced at large scale per year) by 43.1 ± 11.6 and 33.1 ± 7.2%, respectively. CNC recovery from the enzyme-treated feedstock improved by up to 86%, which can reduce the cost of reagents and process operations in acid hydrolysis. SCF using sugar streams generated from the enzymatic treatment of wood pulp will be assessed to realize the development of an economically feasible ethanol/ CNC co-production strategy for the Forestry industry.

CATHERINE TAYS

Bioconversion of methane emissions into biofuels and biofuel precursors (Biomass)

Significant efforts are put forth to improve the conversion of various biomass sources to biofuels, as a path to efficient renewable energy. Many of the processes used for this purpose, like many other industrial activities, release methane, the second-most abundant greenhouse gas, as a by-product. These low to negative value methane emissions can be used as feedstock to methanotrophs – bacteria using methane as sole carbon source – for further conversion to value added biofuels and biofuel precursors (e.g. ethanol, biojet fuel, isoprene). Our project aims to target the challenges related to the industrial implementation of methanotrophs as a platform technology for the production of biofuels and other valuable compounds. This includes work on understanding the physiology and regulation of the microorganisms, identifying optimal process conditions and strategies, developing efficient product recovery methods, and modifying the organisms to improve their productivity and expand their range of economically viable products.

JESSIE BEIER

Speculative Energy Futures: What research-creation contributes to Future Energy Systems (Energy Humanities)

Speculative Energy Futures is a multi-year, collaborative research-creation project on energy transition as a necessary response to addressing climate change. It brings together a carefully selected group of artistic and humanities researchers with science, social science and policy experts to investigate the challenges and potentials of energy transition. Together, participants will produce a research-based art exhibition as well as a series of publications, bringing attention to the importance of arts and humanities perspectives on the social and cultural impacts of energy transition. This presentation will provide a brief overview of research-creation methods and outputs as a strategy for re-imagining energy transition, in addition to showcasing some of the early creative outputs of the Speculative Energy Futures team, including highlights from our first team workshop and updates from the IPCC: Cities and Climate Change Science Conference.

Session 2 - Carbon Capture, Utilization & Storage, Heavy Oil - In-Situ, Heavy Oil - Non-Aqueous Recovery, Land & Water

THEME OVERVIEWS

CARBON CAPTURE, UTILIZATION & STORAGE [CCUS]

Hydrocarbons will continue to serve as an essential energy source while the world transitions to a lower-carbon energy economy, but can we prevent the use of those fuels from contributing to the accumulation of CO_2 in the atmosphere? Existing technologies can capture carbon, but these methods can be costly and energy-intensive. Extracting energy without burning fuels, improving CO_2 capture efficiencies if they are burned, and finding effective ways to store or reuse captured carbon may be essential to ensuring it does not enter the atmosphere.

HEAVY OIL - IN-SITU

According to the 2015-2016 factbook published by Natural Resources Canada, Canada is ranked third and fifth in crude oil reserves and production in the world. Also, fossil (oil, gas, coal) energy production comprises 85% of total energy production in Canada today and nearly half of it is crude oil (42%). Extensive experience has been accumulated in this area at UAlberta. Problems have been well identified and solutions have been proposed through intensive research and service projects over decades with close relationship to industry. This also attracted companies from outside of Canada seeking solutions to their problems on in-situ recovery of heavy-oil. Being familiar with the problems in the area, and future needs, UAlberta can provide long-term solutions.

HEAVY OIL - NON-AQUEOUS RECOVERY

Excessive freshwater use and its eventual capture in tailings ponds represent some of the most concerning elements of the oil sands industry. The requirement for water to be heated as part of the process is also a serious concern, as it demands the use of considerable energy as part of the extraction process. Developing a Non-Aqueous Extraction (NAE) method for recovering oil from the oilsands without the use of water could significantly reduce the environmental and carbon footprint of extracting these resources, and the fundamental science developed to support this process could enable significantly improved cleanup of oilsands sites.

LAND & WATER

As the world moves towards a low-carbon energy future, the legacies of past energy technologies remain a serious concern. Reclamation and restoration of land and water after previous generations of exploitation will be important for our future, and many issues must be addressed. Standards for restoration –– set across decades and based on varying levels of understanding –– must be assessed, while the technologies and methods for land and water reclamation are investigated and refined. True reclamation might take generations, so it is essential to begin broadening and enhancing our knowledge now. We must also begin to foresee potential issues related to new, sustainable energy technologies, so that future generations are not left with the consequences of questions left unasked.

PRESENTATIONS

TSAI-HSING HO

Carbon dioxide dissolution in saline pore fluids [CCUS]

This project is aiming to exploit robust microfluidics, as "Geological/Physical/Chemical/Mechanical Lab on a Chip", which enables clear and high-resolution measurements of CO_2 transport and interactions with pore-fluid and rocks to provide a better understanding and crucial data for accurate numerical modeling. The issue of pore-scale salt precipitation during CCS (Carbon Capture and Sequestration) has attracted more attention since it potentially reduces the injection efficiency and reservoir capacity. To fill the knowledge gap, this study focuses on pore-scale measurements and observations of CO_2 interactions with saline pore-fluid resulting in salt precipitation. The wettability and porosity effects on the precipitation area and nucleation rate will be carried out by high-resolution imaging technology. Future experiments will be conducted at high pressure (P>8MPa) and temperature (T>500) to simulate realistic reservoir environments underground. The critical

values of parameters which inhibits salt precipitation will be verified and concluded.

RAJAN PATEL

Closed-Loop reservoir management using nonlinear model predictive control: A field case study [Heavy Oil - In-Situ]

In deep oil sands deposits, steam-assisted gravity drainage (SAGD) is widely used for bitumen recovery. Closed-loop reservoir management (CLRM) of SAGD involves real-time optimization of well operations.

In this research, two novel workflows using nonlinear model predictive control (NMPC) are proposed for CLRM. First workflow linearizes a nonlinear black box model by estimating an equivalent linear model. Another approach is to use nonlinear dynamic models directly for accurate prediction of the plant states and/or outputs.

Proposed workflows are tested for real-time optimization of steam injection and liquid production rates of a SAGD reservoir located in northern Alberta, Canada. Results reveal that nonlinear black-box models can successfully capture the nonlinearity of SAGD process. Both workflows can control the outputs above desired set-point due to which, net-present-value (NPV) is increased by 24% in CLRM.

Overall, NMPC can successfully improve energy efficiency and greenhouse gas emissions, while considering available surface facilities.

GLORIA OKPALA

Biodegradation of cycloalkanes under different redox conditions (Heavy Oil - Non-Aqueous Recovery)

To address the issue of environ-mental contamination by solvents such as cyclohexane in Non-aqueous extraction (NAE) solids, we seek to conduct a study on the microbial degradation of the solvent under upland (aerobic) and wetland (anaerobic) conditions. Our objectives include; first exploring the potential of microbial communities previously exposed to fluid fine tailings (FFT) or oil sands process water (OSPW) to degrade cyclohexane and/or cyclopentane in both aerobic and anaerobic conditions. Secondly, identifying the activation mechanisms for cycloalkanes degradation in aerobic and anaerobic conditions, and finally applying the established cultures to degradation of cyclohexane in NAE solids. Several small-scale microcosm experiments containing either soil, FFT or OSPW amended with NAE solvent of interest were set up under different redox conditions. The microcosms were periodically monitored for solvent loss or degradation, gas generation (CO_2 and CH4) using GC/GC-MS. Cycloalkane degrading communities will be characterized using 16S rRNA amplicon sequencing.

MUHAMMAD ARSHAD

Low cost biopolymers as adsorbents [Land & Water)

Water is an essential component for almost all types of energy generation including fossil fuels, nuclear and the renewables. This wastewater is often unsuitable for discharge back to the environment and therefore requires treatment. The treatment of industrial wastewater can be difficult and expensive therefore effective and low cost solutions are desirable. Our study takes an innovative approach to treat wastewater using poultry feathers which is an abundant waste material with tremendous potential for large-scale applications. These biopolymers were initially tested against synthetic oil sands process-affected water (OSPW) maintained at ionic strength of 0.05 and spiked with up to 50 ppb of different trace elements (SeIV, Cu, Pb, VV, CrVI). The biopolymers significantly reduced contaminants with removal greater than 90%. Furthermore, the biopolymers reduced upto 66% naphthenic acids in OSPW. Currently, we are in the process of fine-tuning surface properties of developed biopolymers.

SELAMAWIT MESSELE

Catalytic ozonation of naphthenic acid model compound in the presence of carbon materials Integration (Land & Water)

This study examined the preparation, characterization and the use of carbon xerogel (CX) materials as catalyst for the catalytic ozonation of a model naphthenic acid (NA) 1,3-Adamantanedicarboxylic acid (ADA). CX was synthesized by sol-gel method from resorcinol and formaldehyde. The characterization results showed that CX

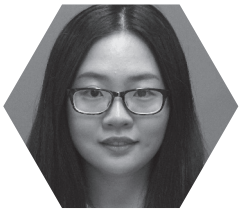
was a mesoporous material with large surface area (573 m2/g) and high pore volume (1.55 cm3/g), which was mainly composed of carbon (93.20%) and oxygen (6.71%). Adsorption, single ozonation and catalytic ozonation experiments were performed using ADA concentration of 50 mg/L, 0.5 g/L carbon materials, and 30 mg/L of ozone, at pH 8. The results show that, after 15 min, less than 5% of ADA was removed by adsorption, while 33% of ADA was removed by single ozonation. For the catalytic ozonation study, among the materials tested, the best performance was obtained using CX, reaching 65% of ADA removal after 15 min of reaction.

PITCHES

KASTURI NAGESH PAI
Post combustion capture of CO_2 using solid sorbents (CCUS)

The capture and separation of CO_2 from the flue gas stream using solid sorbents has energy advantages but isn't well understood. Since the start of the project thousands of materials were screened for their ability to capture CO_2 from flue gas using a robust process simulator. More than a million simulations were performed with a total CPU time of >90000 single core hours. Implementation of multivariate techniques such as PCA, and SVM on the data allowed for the development of pseudo models. These models could lead to the reduction of computational times by as much as three orders of magnitude and allow for accurate and quick screening of these materials. The usage of PCA helped in reducing the dimensionality of the problem by >20 %. Also, Support Vector Machines based regression models helped describe performance outputs accurately with an R2adj of 0.98 for highly nonlinear quantities such as parasitic-energy.

CHANG GAO
Integration of data-driven models for characterizing shale barrier configuration in 3D heterogeneous reservoirs for SAGD operations (Heavy Oil - In-Situ)



Shale barriers may act as flow barriers with adverse impacts on steam chamber development, as observed in numerous field-scale SAGD projects. Efficient parameterization and inference of such heterogeneities in 3D models from production data remain challenging. A novel workflow for SAGD heterogeneity inference by integrating data-driven modeling and production time-series data analysis is presented. Field data are used to build 3D heterogeneous models. Shale barriers are simulated by randomly changing the number, volume, geometry, and locations in 3D reservoir. Input features are extracted from the production time-series data, while output parameters are formulated based on the distribution of shale barriers. Data-driven models are applied to correlate the input and output variables, facilitating the inference of shale characteristics. The final outcome is an ensemble of 3D models of heterogeneity that honor the actual SAGD production histories. This study provides complementary and computationally-efficient tools for inference of shale barriers.

STEPHANIE IBSEN
Invertebrate indicators of land reclamation success (Land & Water)

Alberta's existing regulatory criteria for land reclamation focus on soil and vegetation. With a global focus on resilience and biodiversity there is debate about whether two-dimensional monitoring is sufficient for addressing reclamation trajectories and success and whether multi-trophic level indicators are needed. Reclamation monitoring rarely evaluates multiple ecosystem components, thus relationships among various ecosystem indicators are not fully understood. There are no methods for evaluating soil invertebrates as reclamation success indicators that do not require extensive knowledge and resources. There is a need for practical methods and a full assessment of reclamation indicators to determine if current criteria are adequate.

Session 3 - Geothermal, Non-Electric Infrastructure, Solar

THEME OVERVIEWS

GEOTHERMAL

Canada's geoscape possesses more potential geothermal energy than hydrocarbon energy, but numerous challenges must be overcome if this renewable resource is to be effectively harnessed. Reservoirs of geothermal energy must be located, characterized, and modeled.

The nature of the interaction between rock at reservoir sites and geothermal fluids must be understood, and the potential costs of exploiting them in real-world scenarios must be understood. At the same, new engine technologies must be developed to enable generation of power from geothermal heat sources with non-ideal temperatures.

NON-ELECTRIC INFRASTRUCTURE

Whether for hydrocarbons or new fuels derived from renewable resources, effective methods for storing, handling and transport are essential to the harnessing of energy sources. Infrastructure for movement and storage of these resources must be developed with an understanding of its social, economic, and environmental impacts –– including potential unintended consequences, such as the creation of locked-in emissions, or the stranding of assets.

A base of knowledge related to these questions must be developed, and distributed to planners, users, and decision-makers whose choices can shape our energy future for generations to come.

SOLAR

The sun powers the entire world, providing warmth, light, and sustenance for countless forms of life. Technologies have made it possible to use some of the sun's energy to produce electricity and fuels, but new refinements may allow us to diversify the ways in which solar energy can be generated, stored, and utilized.

By identifying lower-cost materials for use in the construction of solar cells, finding new catalysts to enable different types of production, identifying more efficient methods for market integration, and considering the possibility of solar-derived hydrogen fuels, it may be possible to develop vast energy resources from the most abundant source in our lives.

PRESENTATIONS

EVAN RENAUD

Characterizing geothermal reservoirs within the Western Canadian sedimentary basin (Geothermal)

Hot formation water within sub-surface oil & gas reservoirs has the potential to provide a renewable, base load energy source for western Canadian communities and the provinces of Alberta and British Columbia as a whole. In order to best access this energy we need to understand the subsurface in order to optimize choosing of potential geothermal well targets. Detailed observation of core data in conjunction with petrophysical well data provide an understanding of porous and permeable trends of rock. Two research projects are currently being conducted at Clarke Lake Gas Field near Fort Nelson, B.C. and the South Swan Hills reef complex in Central Alberta. Both locations have considerably hot (~80-110°C) formation water located in mature carbonate oil & gas reservoirs. The first step in providing a suitable plan to access these resources is to have a detailed understanding of the subsurface and its capabilities of fluid flow.

JASON MICHAUD

Designing a low grade heat stirling engine: an opposed piston alpha-type [Geothermal]

Stirling engines are externally heated closed-cycle heat engines, which can be used with numerous types of heat sources, such as geothermal energy or solar energy. Typically, the source temperature is increased to increase the power output; however with low grade heat Stirling engines (LGHSE), with a maximum temperature source below 150 °C, this may not be possible.

Therefore, new design solutions must be implemented in order to maximize the power output and efficiency of the engine. There are several components of the Stirling engine that were determined to be the focus of improvement for a LGHSE, such as the heat exchangers, the piston seals, the drive mechanism, and the materials. Research is currently being conducted in all these areas in order to manufacture an alpha-type LGHSE. A comparison between the previous and current iteration of the engine will be presented, as well as an explanation behind the design decisions.

NEBIYU KEDIR

Definition and Taxonomy for Non-Electric Energy Infrastructure (Non-Electric Infrastructure)

Improving the performance of our energy resources necessitates that our facilities for energy infrastructure be efficient, cost-effective, and safe throughout their lifetime. Risks not common to the other types of infrastructure must be captured effectively, due to the unique and emerging nature of future energy systems technologies. A comprehensive definition of "infrastructure for energy" is developed, with a focus on "non-electric" components. A taxonomy for non-electric energy infrastructure is proposed, to facilitate the assessment of risks and to improve the performance of future energy systems projects. A working taxonomy for a wind farm is proposed for validation of the taxonomy, which will later be applied to other future energy systems projects. The taxonomy will be used as a basis for assessing the impacts of risks and measuring performance during the construction, operation, and maintenance of future energy systems projects to facilitate improved decision-making.

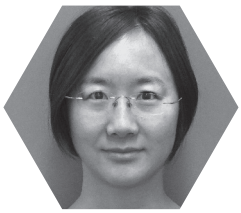
CHAO WANG

Modular Construction of Water Oxidation Photoanodes by Covalent Bonding and Self-Assembly (Solar)

Dye-sensitized photoelectrochemical cells (DSPECs) convert the energy of visible light into chemical bonds through water splitting. We report a reliable method to attach 1,10-phenanthroline (phen) to ITO or TiO2 semiconductors by a C(5)-Osurface single covalent bond. Reaction between the surface phen and the corresponding Ru- or Ir- precursors formed the [Ru(bipy)2(phen)]2+ (bipy = 2,2'-bipyridine) or [Ir(ppy)2(phen)]+ (ppy = 2-phenylpyridine) chromophores grafted at C(5) to ITO or TiO2. We investigated the photoelectrochemical activity of these photoanodes with hydroquinone and triethylamine as sacrificial electron donors over a wide pH range (pH 1-13). The covalent C(5)-Osurface linkage is quite resistant to hydrolysis under basic conditions, unlike phosphonate acid groups.

BING CAO

Optimization of Organic Solar Cell Efficiency via Machine Learning and Design of Experiments (Solar)



Organic solar cells (OSCs) are promising candidates for clean and renewable energy. Improving OSC efficiency is one of the most important tasks on the way toward commercialization. Morphology of the bulk heterojunction, the most important layer within an OSC, depends extensively upon processing. However, conventional optimization is time consuming since only one parameter is optimized at a time. Moreover, there is an associated risk of missing the optimal results since all experimental combinations for all parameters can not be performed. Herein, we report on an approach that uses Design of Experiments (DOE) along with machine learning statistical data analysis to effectively and efficiently optimize solar cell efficiency. Machine learning algorithms are trained to find patterns in datasets while DOE methods allow the exploration of a larger parameter space with fewer experimental trials. Specific examples of concrete improvement of the power conversion efficiency of OSCs will be described.

PITCHES

CALYNN STUMPF

Performance Evaluation of a 3D Printed Low Temperature Difference and Source Gamma Type Stirling Engine (Geothermal)

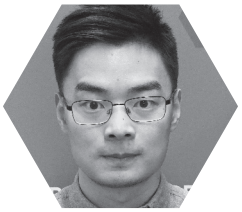
Stirling engines are a type of closed cycle regenerative heat engine that produce a pressure change throughout a cycle driven by the changing of the temperature of a working fluid caused be a thermal source and sink. A gamma type Stirling engine makes use of a displacer piston to shuttle the working fluid between the thermal source and sink, and a power piston to extract the pressure change into work. A numerical model for determining the pressure volume (PV) diagram of the Stirling engine cycle is compared to the experimentally obtained PV diagram. Additionally, an analytical heat transfer model is compared to the experimental working fluid temperature variations.

YAJIE HAO

Fuzzy sets and AHP to model group decision making for energy infrastructure risks (Non-Electric Infrastructure)

Aimed at the improvement and optimization of the performance of available energy resources, risk factors have to be carefully identified, assessed, and quantified. This assessment is inherently associated with problems of decision-making, in which three important facets have to be taken into account: (i) multiple criteria when evaluating various alternatives, (ii) uncertainty originating from the complexity of the problem and its multifaceted nature, and (iii) presence of a group of decision-makers whose inputs are to be reconciled. These factors imply that the decision-making problem falls under the category of multicriteria group decision-making. Its formulation requires the optimization (maximization) of the consistency of individual assessments being provided by decision-makers, as well as the maximization of consensus established among a set of individual rankings. To address these challenges, in the formulation of the problem and its solution, we focus on the concepts of fuzzy sets and the Analytic Hierarchy Process (AHP).

SHENG ZENG



Exploiting Nanophotonics and Plasmonic Hot Electrons for the Production of Solar Fuels (Solar)

Plasmonic hot electrons generated in Au, Cu or Ag nanoparticles (NPs) offer an unconventional route to perform sunlight-driven water-splitting and CO_2 photoreduction. The generation of hot electrons is not controlled by a semiconductor bandgap. Instead the yield and action of hot electrons is dependent on the interplay of a complex set of sequential & competing physical processes such as Landau damping, Drude electron scattering, electron-phonon coupling, strongly coupled electronic transitions, etc. We built new platforms to exploit hot electrons for photocatalysis that also benefit from photonic crystal mediated light trapping effects. Initial results for sunlight-driven water-splitting and CO_2 photoreduction are highly promising.

While noble metals are expensive, the strong amplification of local electromagnetic fields by plasmonic NPs means that a very small quantity of noble metals might be sufficient to obtain a high photocatalytic performance. The Shankar Group is also looking into the noble metal-free plasmonic behavior of metallic ceramics.

Session 4 - Grids & Storage, System Wide

THEME OVERVIEWS

GRIDS & STORAGE

New technologies enable us to exploit renewable energy resources, but truly harnessing their energy requires the ability to control and adapt to the complex interaction between multiple sources and users.

Smart grid technology will enable systems that can adapt to the variation in supply that is common from renewable sources, while new storage technologies will make it possible to retain energy generated at during peak times to be withheld for later use.

Developing hybrid grids that can accommodate both AC and DC power, accommodating distributed generation, and effectively interfacing with legacy grid systems will be essential to our energy future.

SYSTEM WIDE

Understanding energy systems at a system-wide level means recognizing the countless ways that they integrate into our daily lives. From the instant when an energy source is first captured, to the moment you access it by flipping a light switch or starting your engine, it has traveled through a system to reach you. Systems modeling allows us to identify and quantify each step along the way, to simulate the impact of alternative systems, and to predict the potential consequences of change.

System-wide analysis and modeling will never provide a guaranteed forecast of the future, but it can identify possible benefits and disadvantages to change, highlight areas requiring additional study, and help us to consider the viability of an entirely new energy future.

PRESENTATIONS

FARZAM NEJABATKHAH

Hybrid AC/DC Smart Grids Power Quality Control using Single-Phase Distributed Generation Converters (Grids & Storage)

Today, the conventional power systems are evolving to smart grids, where various aspects of the grids, such as distributed power generations, power electronics, machines, communications and markets, are deeply integrated. In general, the next-generation smart grids contain AC and DC subgrids, which are interfaced through power electronics converters. In such systems, unbalance condition is one of the major power quality issues. Due to the distributed loads in such hybrid AC/DC smart grids, centralized unbalance compensation does not work well. The ever-increasing smart single-phase power electronics interfacing converters from distributed generations, energy storages, loads, as well as the AC and DC subgrids interface converters are promising candidate for unbalance condition control. In this work, the power quality issues in hybrid AC/DC smart grids are studied first, with the focus on unbalance condition. Then, a new control strategy of smart single-phase power electronic interfacing converters for unbalance condition compensation is provided.

DANIEL MAY

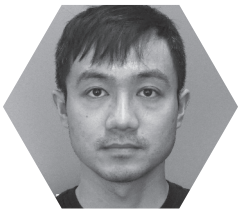
A Future Energy System (Grids & Storage)

As the penetration of renewable and distributed energy resources with modern AC/DC interfaces increase, we face new challenges regarding system maintenance and operation. Simultaneously we have more relevant measurements and data available than ever, making better solutions to these challenges possible. We present a future energy system based on artificially intelligent, autonomous agents, that predict market, producer and consumer behavior.

To this end, a brief overview over deep reinforcement learning is presented. First element to this vision is a new market structure based on a transactional market that enables more robust and efficient, real-time trading strategies to be designed and executed. On this basis, alternative energy management and trading strategies can be designed to leverage the robustness of the market structure. Finally, we discuss implementing intelligent, autonomous agents alongside the trading strategies to take full advantage of the transactional market and the quantity of data available.

XUEHAI TAN

Pompon-like Ir Superstructure Demonstrating Enhanced Activity and Durability toward Electrocatalytic Oxygen Evolution Reaction (Grids & Storage)



Water electrolysis is an important electrochemical process that could convert the intermittent renewable energy to storable chemical fuels. The slow kinetics of oxygen evolution reaction (OER) however limits the performance and the large-scale application of the process. Here, we report a three-dimensional (3D) Ir superstructure that demonstrates promising OER electrocatalytic activity and durability in acidic electrolyte. The Ir superstructure consists of primary building blocks of Ir nanodendrites growing radially outwards. Such pompon-like superstructure combines the beneficial properties of both the nanoscale and the highly ordered surfaces. While the dendritic nanostructure achieves good mass transport and utilization of Ir surface area, the enhanced crystallinity along the growth direction of each dendrite - with lower density of surface defects comparing to 2 nm Ir nanoparticles - also leads to less Ir dissolution. Our 3D Ir superstructure should have positive impact on improving polymer electrolyte membrane-based water electrolyzers.

TIM WEIS

Price impacts of renewable energy diversity in Alberta (Grids & Storage)

As Alberta phases out coal, renewable forms of electricity generation are expected to play an increasingly significant role as their costs rapidly decline. In 2017, Alberta contracted wind energy for levelized costs lower than any other new form of electricity generation, renewable or otherwise. Variable output renewable technologies such as wind and solar tend to suppress their own market capture prices by offering zero marginal cost bids. Falling costs spur additional development, further suppressing prices realized to renewable generation facilities that are located in within correlated resources. This research integrates new wind data made available by Environment Canada into an hourly electricity market model to examine scenarios of increasing geographic and technology diversity into areas of lower energy density, but higher degrees of uncorrelated resources and its impact on future renewable energy development in Alberta.

ANKIT GUPTA

Integrated Assessment of Environmental Footprints for Energy Scenarios [System Wide]

Much of the current focus on climate change mitigation is on developing and evaluating greenhouse gas (GHG) emission reduction methods. The impacts that these methods have on water supply and demand have not been rigorously evaluated. This research aims to develop integrated water and GHG footprints for various energy pathways in Canada's oil and gas industry and power sectors. Development of an integrated water-energy systems model will provide capabilities to assess long term environmental impacts. Localized analysis of water demand and supply is being conducted through creation of a Water Evaluation and Planning (WEAP) model. An interconnected Long-range Energy Alternative Planning (LEAP) model will analyze energy use and associated GHG emissions. The results will provide insight into how GHG mitigation strategies will impact water demand and availability. This can create better understanding of the water-energy nexus and help to formulate sustainable development policies based on quantitative methods.

PITCHES

BALAKRISHNAN NAGARAJAN

Design and Development of Low-cost Flywheel Energy Storage Systems [Grids & Storage]

Flywheel Energy Storage Systems (FESS) have traditionally been considered for applications requiring high-power capacity. Energy storage in FESS is accomplished by a fast spinning rotor coupled to a motor/generator unit. FESS have a wide range of applications in power grids and transportation. Rapidly evolving technologies like high performance composite materials, high efficiency electrical machines and low-friction bearings are pushing FESS toward new applications. Current research focuses on the prediction of energy losses, long-term system behavior, and integrating electrical machine functionality into flywheel rotors. Losses were studied experimentally, and empirical models were created for loss predictions. Techniques assessing long-term behavior are being developed along with design approaches to ensure sustained performance. Integrating electrical machine functionality into rotors is accomplished by structuring magnetic particles into the polymer matrix of fiber-reinforced composite rotors. Fundamental studies to develop both equipment and materials are being conducted.

MICHAEL MOORE

Analysis of polymer electrolyte water electrolysis by numerical modeling and simulation [Grids & Storage]

Hydrogen production and underground storage is one of the only viable solutions to store amounts of intermittent energy from renewable sources. Polymer electrolyte water electrolysis (PEWE) units in the MW range however are only recently being investigated. In order to develop such large scale devices, numerical modeling and optimization is of paramount importance. However, the operation of PEWE cells has not been extensively modelled to date and models in the literature contain numerous deficiencies. For example, the equilibrium potential and kinetics of the oxygen evolution reaction are poorly captured. In this work, a literature review of previous models is presented and used to develop a simple 0-D model with an improved formulation of the Butler-Volmer equation and this reference state. The model is used to analyze experimental data obtained using an in house 5 centimeter squared electrolyzer cell.

TANVEER MEHEDI

Life Cycle Assessment of Energy System Transitions: the case of solar energy in Alberta [System Wide]

Solar energy has been gaining interest among the stakeholders in Alberta as the province has the highest annual sunlight in Canada. Although solar photovoltaic panels are usually considered as a safe and reliable source of electricity with minimal greenhouse gas emissions, the impacts from other life cycle stages such as the resource extraction, main components manufacturing and transportation are considerable. Around 60% of the solar photovoltaic panels used in Alberta are manufactured in China, where carbon-intensive fuels are used. In addition, the transportation also contributes hugely to the overall greenhouse gas emissions. The main purpose of this research is to perform a comprehensive life cycle assessment to evaluate the economy-wide and the global impacts of solar-based renewable energy in Alberta. The results obtained through this project will help energy policymakers to identify the environmental hotspots in the solar energy pathways for Canada specific scenarios and take action accordingly.

Poster Presentations

BIOMASS

1. ADETOYESE OYEDUN

Biobattery concept: Decentralized production of fuel from forest biomass, agriculture residue and municipal solid waste

Pyrolysis is one of the technologies which convert biomass/wastes directly into bio-oil. There are significant challenges with the bio-oil produced from this pathway such as low density, low energy content and low pH which makes it difficult to upgrade to high grade fuels. Therefore, the thermo-catalytic reforming technology which is the core of the biobattery concept is an intermediate pyrolysis technology where conditioned feedstock (forest biomass, agricultural residues and organic portion of MSW) is heated in pyrolytic conditions to produce bio-oil, char and gases is expected to solve the challenges with the current conversion pathways. These products can be used in the oil sands, aviation and power sectors. In this study, the overview of the concept of biobattery will be presented and efforts on how the concept can help to achieve a landfill-free Alberta while reducing the GHG emission burden of the province will be discussed.

2. JIE WANG

Development of Advanced Processing Strategies for Ethanol/CNC Co-production

This project uses advanced fermentation strategies to improve ethanol productivity from sugar streams recovered from partial degradation of wood pulp by cellulase. Selective enzymatic treatment was designed to efficiently recover a high value product, cellulose nanocrystals (CNC), from acid hydrolysis of enzyme-treated feedstock. In parallel, a self-cycling fermentation (SCF) approach was mimicked in shake flasks to elevate ethanol productivity. Compared with batch fermentation, SCF improves ethanol volumetric productivity (titer of ethanol produced per time) and annual ethanol productivity (amount of ethanol produced at large scale per year) by 43.1 ± 11.6 and 33.1 ± 7.2%, respectively. CNC recovery from the enzyme-treated feedstock improved by up to 86%, which can reduce the cost of reagents and process operations in acid hydrolysis. SCF using sugar streams generated from the enzymatic treatment of wood pulp will be assessed to realize the development of an economically feasible ethanol/CNC co-production strategy for the Forestry industry.

3. YANAN ZHENG

Potential ethanol biorefinery sites in Alberta based on agricultural residues

Alberta produces large quantities of agricultural crop residues that could be used as feedstock for an emerging bioenergy industry. But concentrations of available feedstocks, and other economic features, are a key consideration in selecting potential biorefinery sites. Using 2015 crop residue data from the Bio-resource Management System (BRIMS), and GIS-based techniques, we examine the spatial distribution of available feedstock, and other economic considerations, with the aim of identifying possible future biorefinery sites. Candidate sites are selected and mapped based on the amount of residues within a 40 km radius needed to supply a minimum plant capacity of 1.8 Mt/yr. We also consider economical transport viability and workforce availability. Of the identified sites, the five sites with the largest available volumes are found within the counties of Flagstaff, Kneehill, Sturgeon, Ponoka, and Minburn. The present study provides a starting point for investigating economic viability and may inform future site selections.

4. CATHERINE TAYS

Bioconversion of methane emissions into biofuels and biofuel precursors

Significant efforts are put forth to improve the conversion of various biomass sources to biofuels, as a path to efficient renewable energy. Many of the processes used for this purpose, like many other industrial activities, release methane, the second-most abundant greenhouse gas, as a by-product. These low to negative value methane emissions can be used as feedstock to methanotrophs – bacteria using methane as sole carbon source – for further conversion to value added biofuels and biofuel precursors (e.g. ethanol, biojet fuel, isoprene). Our project aims to target the challenges related to the industrial implementation of methanotrophs as a platform technology for the production of biofuels and other valuable compounds. This includes work on understanding

the physiology and regulation of the microorganisms, identifying optimal process conditions and strategies, developing efficient product recovery methods, and modifying the organisms to improve their productivity and expand their range of economically viable products.

5. MAHDI VAEZI

Integration of Pipeline Hydro-transport and Hydrothermal Conversion Technologies to Produce Biofuels

This research project is aimed at assessment of agricultural and forest residue biomass for transportation via pipeline, and conversion using hydrothermal technologies to produce biofuels. Pipeline hydro-transport of agricultural and forest residue biomass benefits from economy of scale, as well as eliminating traffic congestion and environmental issues of overland transportation. Hydrothermal processing is also a thermo-chemical conversion technology to process high moisture content biomass. This research will develop techno-economic model of integrated pipeline hydro-transport and hydrothemal conversion technologies. The technical information on pipeline hydro-transport will be obtained through experimental measurements on a lab-scale pipeline facility. Technical data on hydrothermal processes will be achieved via computational modeling using AspenPlus as well as experimental studies using a small-scale hydrothermal reactor. Combined technical and economic data will provide a techno-economic model to estimate the cost of producing biofuels from residues delivered via pipeline.

6. YU FENG

Impacts of Data Assumptions on Potential Residue Supplies for Bio-fuel Feed-stock from Agriculture in Alberta

The potential supply of crop residues for producing biofuels in Alberta is uncertain, and may be heavily dependent on assumptions used in compiling data. The current state of the art data for Alberta is available from BRIMS (The Bio-Resource Information Management System), which may be used to help identify potential sites for biofuel production facilities. We investigate the sensitivity of assumptions involved in compiling feedstock data regarding the availability of feedstock supplies. Though our general approach is similar to that used in BRIMS, we investigate the sensitivity of results to: differences in spatial resolutions, crop yields, crop rotations, and conversion factors that estimate residuals for different crops. The results are compared and contrasted with the BRIMS data. This study will provide information regarding means of generating data for assessments of economic viability of potential biofuel facility locations.

7. MIRANDA STAHN

Cell lysis and enhanced product recovery from methanotrophic bacteria

Methanotrophic bacteria have garnered interest due to their ability to utilize methane from impure sources, such as industrial waste streams, and convert it to valuable products, such as biofuels and biomaterials. However, challenges associated with the extraction and recovery of products from these bacteria prevent the broad deployment of this technology in industrial settings. In order to facilitate the recovery of intracellular products, we are investigating the use of bacteriophages, viruses that infect bacteria, to lyse cells post-production. A second and complementary approach relies on the use of switchable polarity solvents – which can be alternated between a water-miscible and water-immiscible form through the addition or removal of CO_2 – to extract and separate products from cellular matter. In addition, these solvents can be recycled with minimal waste or energy requirements by reverting them to their water-miscible form. Together these will simplify downstream processing and reduce recovery costs and environmental impacts.

8. SHIBASHIS DAS

Development of a Methanotroph Chassis: Genetic Engineering of Methylomicrobium album BG8 for production of value-added products

Methylomicrobium album BG8 is a methanotrophic bacteria notable for a rapid growth rate utilizing single carbon (C1) compounds, i.e. methane and methanol. This trait, along with its rich genetic potential, makes the strain a candidate for the development of an industrial biological chassis for the conversion of C1 compounds into value-added products such as biojet fuel and biopolymers. This requires the development of new functional genetic tools to enable a larger library of value-added products from M. album BG8. This will allow the manipulation of the organism into a suitable platform that efficiently directs carbon flow into products and away from storage or oxidative fates. Products of interest include isoprene, a valuable platform chemical and precursor to many advanced

biofuels. Here, we describe a plasmid-based expression system and a marker free deletion system developed to transform BG8 and achieve increased levels of isoprene production.

9. CATHERINE TAYS

A multi-level "-omics" approach to the study of the growth regulation of methanotrophs

Methane, a common industrial by-product, is a potent greenhouse gas and significant contributor to global warming. Fortunately, it can also serve as feedstock to a specialized class of bacteria known as methanotrophs, which can convert it to value-added products such as biofuels and biopolymers. Before industrial implementation of these bacteria, a thorough understanding of their physiology and regulation must be achieved. This starts with a wide survey of their genomic inventory and global RNA regulation, via transcriptomics, when given different carbon (methane/methanol) and nitrogen (ammonium/nitrate) sources. This will be complemented by more in-depth studies of industrially-promising strains, analyzing the regulatory effect of other conditions such as copper content, as well as integrating metabolomics analysis to understand how processing conditions affect the function, structure, or metabolism of these species. The development of this multi-level "-omics" platform will lead to substantially more efficient optimization processes.

10. FATEMEH BAKHTIARI ZIABARI

Optimizing methanotroph biotechnology through growth strategies and strain adaptation

Methane is a potent greenhouse gas and common industrial by-product. This compound can be used as feedstock for methanotrophic bacteria, which can convert it into valuable products including advanced biofuels. Although enticing, the industrial implementation of this technology necessitates significant improvements in cell growth and product yield. This will be achieved through 1) assessment of growth characteristics under various nutrient conditions – identifying preferred conditions per species and assessing which strains may be better candidates for industrial applications; 2) advancement of bioreactor strategies – adapting fed-batch and self-cycling fermentation for these bacteria; and 3) adaptation of strains to industrial conditions – including acidic conditions of forestry effluent streams containing methane or methanol – for increased survival and improved growth kinetics.. Together, these aspects of process development will lead to a highly efficient, reliable system of methanotroph-biotechnology towards the conversion of harmful waste streams into useful bioproducts.

CARBON CAPTURE, UTILIZATION & STORAGE

11. KASTURI NAGESH PAI

Multivariate Data Analysis of Post Combustion Capture of CO_2 Using Solid Sorbents

The capture and separation of CO_2 from the flue gas stream using solid sorbents has energy advantages but isn't well understood. Since the start of the project thousands of materials were screened for their ability to capture CO_2 from flue gas using a robust process simulator. More than a million simulations were performed with a total CPU time of >90000 single core hours. Implementation of multivariate techniques such as PCA, and SVM on the data allowed for the development of pseudo models. These models could lead to the reduction of computational times by as much as three orders of magnitude and allow for accurate and quick screening of these materials. The usage of PCA helped in reducing the dimensionality of the problem by >20 %. Also, Support Vector Machines based regression models helped describe performance outputs accurately with an R2adj of 0.98 for highly nonlinear quantities such as parasitic-energy.

12. ALIREZA RANGRIZ SHOKRI

Non-Isothermal Reservoir Geo-mechanical Modeling at Aquistore

To assess the capacity of subsurface formations to receive and safely store CO_2 over long periods of time, modeling multiphase flow, heat transport and geomechanical changes that may occur due to CO_2 sequestration, is needed. One of the major gaps in modeling cold CO_2 injection into deep saline aquifers is the lack of large-scale coupled thermo-hydro-mechanical code which could include both non-isothermal multiphase flow and geo-mechanical stress-strain equations. In addition, experimental thermo-hydro-mechanical data are required to feed the non-isothermal simulations. In this presentation, the numerical and experimental methodologies, which enable us to model various issues related to CO_2 sequestration, including injectivity index and downhole injection temperature, phase behaviour, density mixing, changes

in formation porosity and permeability, risk of leakage and ground subsurface deformations are discussed.

13. WANYING PANG

Co and Fe co-doped Pr0.5Ba0.5MnO3 Perovskite as both Air- and Fuel-Electrode Materials for CO_2 electrolysis

Carbon dioxide (CO_2) emission enters the atmosphere mostly through burning fossil fuels which results in severe climate change in the recent decades. Recently, perovskite oxides with nanoparticle exsolution have attracted great attention in high temperature CO_2 electrolysis and therefore afford chemical storage of available electricity that can both stabilize and extend the utilization of renewables. In this work, we present a strategy of Co and Fe co-doping Pr0.5Ba0.5MnO3(PBMCF) perovskite and infiltrating PBMCF catalyst into YSZ scaffold instead of traditional mixing method to facilitate CO_2 reduction. Theoretical calculations are carried out to explore the mechanism of CO_2 adsorption and activation on the surface with exsolved Co and Fe nanoparticles. Combined experimental and density functional theory calculations show that the prepared catalyst with the exsolution of metallic nanoparticles exhibits promising capability such as improved catalytic activity and durability to convert CO_2 into value-added fuels.

14. MOHAMMAD JAVAD AFROUGHI

Methane decarbonization in hot products of laminar premixed flames

This study investigates hydrogen (H2) production, and properties of generated carbon during methane decarbonization. Different flow rates of methane (0.5 to 5 SLPM) are injected in an oxygen deficient gas stream of propane- and methane-air premixed flames, with maximum temperature of 1170 and 1135 °C, respectively, to be decarbonized. Gaseous concentrations in formed products are measured by a gas chromatographer, and size distribution of generated particles is measured by a scanning mobility particle sizer (SMPS). Results show that residence time (inversely proportional to decarbonized methane flow rate) is the dominant predictive of H2 production and carbon properties, while type of the premixed fuel only affects size distribution of particles. H2 production and median size of particles decrease from 69% to 12% (78% to 10%), and from 58 to 18 nm (21 to 18 nm) following the injection of 0.5 to 5 SLPM of methane to the propane-air (methane-air) premixed flame.

15. SHAWN ZHANG

Photoelectrochemical Reduction of CO_2

Carbon dioxide emission have a significant impact on climate change. Photoelectrochemical (PEC) reduction of CO_2 is a promising method to reduce CO_2 emission while producing valuable products. Using solar energy and electricity from renewable sources, this undesired gas can be converted into fuels such as carbon monoxide, hydrogen, and a variety of hydrocarbons. Our group have been researching and screening suitable catalyst for tuneable syngas (CO+H2) production. Preliminary experimental results indicated few possible candidates as suitable catalyst materials, including Cu2O and CuSnOx. Further works are needed to achieve higher faradaic efficiency towards targeted products and improve photocurrent response of the materials through exploring different structure and morphology.

ENERGY HUMANITIES

16. JESSIE BEIER

Speculative Energy Futures: What Research-Creation Contributes to Future Energy Systems

Speculative Energy Futures is a multi-year, collaborative research-creation project on energy transition as a necessary response to addressing climate change. It brings together a carefully selected group of artistic and humanities researchers with science, social science and policy experts to investigate the challenges and potentials of energy transition. Together, participants will produce a research-based art exhibition as well as a series of publications, bringing attention to the importance of arts and humanities perspectives on the social and cultural impacts of energy transition. This presentation will provide a brief overview of research-creation methods and outputs as a strategy for re-imagining energy transition, in addition to showcasing some of the early creative outputs of the Speculative Energy Futures team, including highlights from our first team workshop and updates from the IPCC: Cities and Climate Change Science Conference.

17. CHARLES STUBBLEFIELD

iDoc: Engineering Just Futures

As Heidegger points out, humans have a quality of "thrownness" about them. We are all born into a world of pre-existing

nations, economies, institutions, cultures, gender relations, and techniques for understanding the world around us. All of which influence how we perceive and interact with the world, and more pressingly how we understand and attempt to address ecological crises. As such, the various projects under the banner of Just Futures seek to engage with and foster communication between divergent and sometimes antagonistic conceptions of ecological crises and visions of the future. Specifically, iDoc's aim is twofold; first, to critically question those conceptions and power relations by which various FES themes, government organizations, and activists operate; and second, to provide a common space for dialogue between such groups, so as to foster wider, more inclusive futures. This presentation will serve to introduce FES members to iDoc, and to ignite such dialogue.

18. SIMON ORPANA

Petrocultures in Everyday Life

Our poster will showcase two graphic narratives in development by TECS HQP Simon Orpana. These projects address questions of energy transition qualitatively rather than quantitatively, mapping the connections between lived personal experience and large-scale forms of energy infrastructure. A wholesale change in energy form is not only technical but also social and cultural, with implications for the "structures of feeling" - the habits, beliefs, and desires - that shape everyday life. The representational possibilities afforded by graphic narrative can enable the production of new ways of seeing and imagining energy transition and energy futurity as well as the circulation of such new perspectives among diverse publics. One of the graphic narratives in development is a primer on petroculture, informational and informative, while the other, longer and more conceptually challenging, uses the aesthetic possibilities of the graphic narrative form to explore the complicated, sticky affects bound up with energy impasse and energy transition.

GEOTHERMAL

19. CALYNN STUMPF

Performance Evaluation of a 3D Printed Low Temperature Difference and Source Gamma Type Stirling Engine

Stirling engines are a type of closed cycle regenerative heat engine that produce a pressure change throughout a cycle driven by the changing of the temperature of a working fluid caused be a thermal source and sink. A gamma type Stirling engine makes use of a displacer piston to shuttle the working fluid between the thermal source and sink, and a power piston to extract the pressure change into work. A numerical model for determining the pressure volume (PV) diagram of the Stirling engine cycle is compared to the experimentally obtained PV diagram. Additionally, an analytical heat transfer model is compared to the experimental working fluid temperature variations.

20. CEDAR HANNESON

Structural heterogeneity, thermal spring distribution, and geothermal energy potential along the Southern Rocky Mountain Trench

Trench Several thermal springs occur along the Southern Rocky Mountain Trench (SRMT), indicating the possibility of a fault-hosted geothermal system. We compile structural and geophysical data from the vicinity of the SRMT to provide a synthesis of the interpreted subsurface. Locations and estimated circulation depths of thermal spring systems along the SRMT are compared against mapped geological structures, and simple hydrogeological models are proposed for each spring. Particular attention is paid to the Valemount area where there is commercial interest in geothermal exploration; new cross-sections through this region are created using existing geological data and new magnetotelluric data. We evaluate the broad relations between fault kinematics and spring occurrence, and consider possible reasons for the notable lack of thermal springs between the latitudes of 51°N and 52.5°N. There is much uncertainty regarding the kinematic history and subsurface geometry of several faults, and further targeted structural and geophysical mapping is required.

21. MICHAEL NICOL-SETO

Drive mechanism design for the improvement of Stirling cycle heat engines

The Stirling heat engine operates on a closed thermodynamic cycle that converts thermal potential energy to mechanical work via the cyclic heating, expanding, cooling, and compressing of a gaseous working fluid. Most practical Stirling engines employ piston cylinder assemblies and slider crank mechanisms to extract work from the gas, but the kinematics of these mechanisms results in deviation from the ideal dis-

continuous thermodynamic cycle and lower engine efficiency. Discontinuous boundary motion in the engine mechanism can potentially improve the thermodynamic performance of low temperature Stirling engines. Experiments are being conducted using computer controlled engine analogues to examine how different boundary motion alters the pressure and temperature indicator diagrams compared to the theoretical thermodynamic cycle. The results will be used to develop practical mechanisms that achieve an improved cycle motion that will be tested on a lab scale Stirling engine.

22. STEVEN MIDDLETON

Development of a 3rd Order Model of Stirling Engine Performance

Stirling engines are an economically tasteful option to produce electricity from low-grade geothermal heat. Modeling drives the design of Stirling engines. Currently, second order models are used to design Stirling engines in the Dynamic Thermal Energy Conversion Laboratory (DTECL). These models use an ideal reference cycle and decoupled losses to estimate engine performance. However, the models are incapable of determining the natural running speed or response of the engine to loads or interacting losses. Third order models are one-dimensional simulations of the engine using the governing equations of kinematics, fluid dynamics and heat transfer. Therefore, coupling the loss mechanisms in the engine can be undertaken, increasing the relevance and accuracy of the model. DTECL aims to develop a third order model for Stirling engines. A robust, modular model is currently in the planning stage of development. The poster will present the framework and progress of the model.

23. DAVID MILLER

A Low-Grade Heat Franchot-Stirling Engine

A primarily 3D printed, low grade heat Franchot-Stirling engine (FSE) is under construction in the Dynamic Thermal Energy Conversion Laboratory (DTECL) to provide insight on the feasibility of the FSE to produce electricity from low-grade geothermal sources (< 100 °C. The FSE is a specific configuration of double-acting Stirling engine with two cycles with 180 ° phase between them. Double acting Stirling engines reduce mechanical losses by doubling the number of power producing cycles per drive mechanism. Other inherent advantages of the FSE are balanced pressure between the two cycles, more continuous power production, increased power density and freedom to vary the phase angle of individual cycles. However, the FSE configuration has larger forces to bear in its drive mechanism and pressure reversal across its piston seal. The poster will present any available engine data and the design strategy of the DTECL FSE.

24. GABRIEL SALATA

Approaches for improving the gas sealing capacity of a 3D printed ABS cylinder

3D printing or additive manufacturing technology is being used as a development technology in the research and investigation of Stirling engines for low level heat recovery. This is due to its capability of creating complex geometry parts faster and cheaper than the traditional machining processes. The process develops air gaps at different % infill arrangements due to the layer-by-layer manufacturing process and therefore do not make 3D printed parts applicable in general for components where sealing is important. This study aims to address and understand the effect of coating 3D printed Acrylonitrile butadiene styrene (ABS) cylinder and compare its capacity to withstand pressure among three different samples: raw 3D printed ABS, coated with epoxy and spray painted.

25. MOUHAMMED EL HASSAN, ALEXANDER HUNT

Investigating the Flow Dynamics and Heat Transfer in Reciprocating Stirling Engine Flows

Once mechanical losses have been minimized, the effects of heat transfer are likely to remain a major factor limiting Stirling engine efficiency. Previous research studies estimated the overall heat transfer in heat exchangers subjected to reciprocating flow without investigating the microscopic fluid flow and heat transfer behavior. Also, conflicting results for predicting the flow regime and heat transfer coefficients were shown in the literature. In order to mimic the actual situation encountered in Stirling engines, the interactions between the thermal and viscous boundary layers need to be understood. A particular focus will be on the vortex dynamics and its effect on the temperature distribution and convective heat transfer. Current work will review the research available in the literature in this area. This is being used to design and develop an experiment flow systems and appropriate optical diagnostic systems to investigate the temperature an and velocity field simultaneously.

GRIDS & STORAGE

26. SUNNY KUNG

Multiport Modular Multilevel Converter for DC Systems

Multiport HV DC-DC converters are required to facilitate future HVDC infrastructure with the ability to interconnect and manage power flow between multiple HVDC networks. Existing topologies offer limited modularity and scalability, making them difficult to implement in the fast-growing HVDC industry. In this work, a multiport modular multilevel converter (MP-MMC) is proposed as the first truly modular multiport HV DC-DC converter. The MP-MMC is made up of multiple sub-converters that can be controlled individually with de-centralized controllers, allowing easy reconfiguration and high reliability of the converter power circuit. This work uses assumed design cases to compare the MP-MMC with other prominent multiport HV DC-DC converters based on modularity, reliability, semiconductor effort, magnetics requirement, and fault-blocking implications. Operation and performance of the MP-MMC are verified by simulation.

27. MICHAEL BARDWELL

Photovoltaic Maximum Power Point Tracking Design for Communities

This contribution presents a start to finish PV Maximum Power Point Tracking (MPPT) design developed on an Internet of Things (IoT) platform. Implementation of an adapted MPPT algorithm in C and Python is presented alongside simulation results. Capabilities of alternative IoT hardware are discussed. Statistical analysis is performed on historical irradiance data to deliver irradiance slope estimates within a confidence interval. A community test case shows that efficient MPPT using inexpensive IoT hardware is possible, with the added benefit of readily available data for other digital services. This paper also points out the lack of consistent framework for PV efficiency evaluation.

28. BALAKRISHNAN NAGARAJAN

Design and Development of Low-cost Flywheel Energy Storage Systems

Flywheel Energy Storage Systems (FESS) have traditionally been considered for applications requiring high-power capacity. Energy storage in FESS is accomplished by a fast spinning rotor coupled to a motor/generator unit. FESS have a wide range of applications in power grids and transportation. Rapidly evolving technologies like high performance composite materials, high efficiency electrical machines and low-friction bearings are pushing FESS toward new applications. Current research focuses on the prediction of energy losses, long-term system behavior, and integrating electrical machine functionality into flywheel rotors. Losses were studied experimentally, and empirical models were created for loss predictions. Techniques assessing long-term behavior are being developed along with design approaches to ensure sustained performance. Integrating electrical machine functionality into rotors is accomplished by structuring magnetic particles into the polymer matrix of fiber-reinforced composite rotors. Fundamental studies to develop both equipment and materials are being conducted.

29. MICHAEL MOORE

Analysis of polymer electrolyte water electrolysis by numerical modeling and simulation

Hydrogen production and underground storage is one of the only viable solutions to store amounts of intermittent energy from renewable sources. Polymer electrolyte water electrolysis (PEWE) units in the MW range however are only recently being investigated. In order to develop such large scale devices, numerical modeling and optimization is of paramount importance. However, the operation of PEWE cells has not been extensively modelled to date and models in the literature contain numerous deficiencies. For example, the equilibrium potential and kinetics of the oxygen evolution reaction are poorly captured. In this work, a literature review of previous models is presented and used to develop a simple 0-D model with an improved formulation of the Butler-Volmer equation and this reference state. The model is used to analyze experimental data obtained using an in house 5 centimeter squared electrolyzer cell.

30. TAGHI AMIRI

High Performance Tubular Solid Oxide Fuel Cell based on Ba0.5Sr0.5Ce0.6Zr0.2Gd0.1Y0.1O3-δ Proton Conductor Electrolyte

For any successful energy storage solution, a high performance converting device is essential. In this work, synthesis and characterization of tubular full cell based on Ba0.5Sr0.5Ce0.6Zr0.2Gd0.1Y0.1O3-δ (BSCZGY) electrolyte have been investigated. Anode-supported Ni - yttria-stabilized zirconia

fabricated via slip casting; BSCZGY electrolyte and BSCZGY - La0.6Sr0.4Co0.2Fe0.8O3 as cathode was coated using dip coating. The chemical compatibility of fuel cell components at sintering temperatures have been investigated by X-ray diffraction, and no severe reactions were detected. The electrochemical examination showed superior performance achieving a maximum of 1 W/cm2 at 850 °C, among the best compared to cells reported earlier and reaching one of the highest reported on proton conductor electrolyte elsewhere. Electrochemical Impedance Spectroscopy was used to measure the behavior of the cell at different temperatures and a detailed analysis was done to distinguish the contribution of ohmic and polarization resistance. Long-term stability under load showed no significant degradation.

31. KAYLA LUND

Energy storage and Alberta's energy policies

This poster explores the future of Alberta's electricity market as the province transitions away from coal and toward gas and renewables and as the province adapts to a new capacity market to complement the existing energy market. We will present 4 key results. First, we look at the evolution of the capacity and generation mix in Alberta. Second, we look at the impact of changes in renewables policies and other factors on new generation deployment. Third, we look at the implications for price. Finally, we look at the implications for Alberta's electricity sector emissions. Results are generated using our implementation of the Aurora XMP electricity model

32. YANG WANG

Power System Condition Monitoring Using Synchronised Waveforms

Nowadays the power system is becoming more and more complex in structure, operation and control mainly due to the proliferation of power-electronic-controller-based devices, such as distributed generations (DGs) and high voltage direct current (HVDC) transmission. One emerging concern is the instable interaction between various power electronic controllers with the system grid. To address this issue, our research proposes a novel condition monitoring system based on synchronized waveform measurements. The function of the system includes: 1) detecting the instability phenomenon in the system based on the measured waveform data; 2) diagnosing which power electronic controller causes the instability problem; 3) deciding an optimal remedial action to mitigate the problem.

33. RODRIGO CASTRO-MARTINS

Optimal Component Sizing for Peak Shaving in Battery Energy Storage System for Multiple Industrial Clients

Recent attention on industrial peak shaving applications sparked an increased interest in battery energy storage. Among other studies, there have been several reports examining optimal sizing of such storage systems for individual clients which results in the battery energy storage system standing idle most of the time. In this context, this work proposes a new business model where battery energy storage is offered as a service by a new stakeholder. This new model allows sharing a single battery storage system among multiple clients. The results show that sharing batteries in peak shaving applications for multiple clients shortens the payback period. The results also show that while batteries used in peak shaving applications are sensitive to calendric aging, the depth of discharge cycling is not relevant. That is an important observation that will simplify relevant optimization studies and thus contribute to more widespread application of industrial peak shaving systems.

34. SHIDA (STEVEN) ZHANG

Economy of Residential Photovoltaic Generation and Battery Energy Storage in Alberta, Canada

Economic analysis of installing photovoltaic generation combined with battery energy storage in residential homes in Alberta was performed by comparing the lifetime net present values of three different system configurations: grid only, photovoltaic generation alone, and both photovoltaic generation and battery energy storage. The study was performed using generation and load data from a photovoltaics-equipped home in Edmonton, Alberta. The addition of a battery energy storage system was simulated using an optimized energy management controller. Parameter explorations were performed for combinations of equipment cost, energy prices, and energy trading schemes. The results show that for equipment and energy prices in 2017, a system with photovoltaic generation is equivalent to a grid only system. The cost of adding a battery cannot be recovered through energy savings alone, although this configuration is more reliable. These systems will become favorable in the future if system costs decrease by approximately 25 percent.

35. SAJAD VAFAEENEZHAD

Solid Oxide Electrolysis Cell

The purpose of this project is to develop an optimized microstructure for solid oxide electrolysis cells (SOEC). The microstructure of the cells can directly affect the electrochemical performance of the cell. Since September 2017, we could find the best sintering condition to develop a perfect planar support for the cell without any deformation or delamination. The behavior of different parameters such as the porosity inside the support, three-phase-boundary (TPB: the active region in functional layer on which electrochemical reaction takes place) condition, percolation of Ni particle (the portion of interconnected Ni particles as electronically conductive phase) is being studied. We are also trying to understand the relation between the raw materials' characteristics (characterized by BET, DLS, XRD, XRF and SEM) and the evolution of microstructure (such as Ni migration and agglomeration or loss of Ni percolation) at high operation condition.

HEAVY OIL - IN-SITU

36. CHANG GAO

Integration of Data-Driven Models for Characterizing Shale Barrier Configuration in 3D Heterogeneous Reservoirs for SAGD Operations

Shale barriers may act as flow barriers with adverse impacts on steam chamber development, as observed in numerous field-scale SAGD projects. Efficient parameterization and inference of such heterogeneities in 3D models from production data remain challenging. A novel workflow for SAGD heterogeneity inference by integrating data-driven modeling and production time-series data analysis is presented. Field data are used to build 3D heterogeneous models. Shale barriers are simulated by randomly changing the number, volume, geometry, and locations in 3D reservoir. Input features are extracted from the production time-series data, while output parameters are formulated based on the distribution of shale barriers. Data-driven models are applied to correlate the input and output variables, facilitating the inference of shale characteristics. The final outcome is an ensemble of 3D models of heterogeneity that honor the actual SAGD production histories. This study provides complementary and computationally-efficient tools for inference of shale barriers.

37. THOMAS DI PIETRO

Mass transfer at an organic solid – organic liquid interface within sandstone under creeping flow conditions

There is a growing recognition that knowledge gaps related to the molecular and phase state complexity of hydrocarbon resources, and their interactions within production and processing environments have begun impeding development of new or improved processes that protect the natural environment and provide the ongoing social licence to operate in an increasingly regulated industrial sector. This work focuses on understanding mass transfer between a solvent and undisturbed hydrocarbon resource within reservoir rock. Solvent injection is one of a suite of proposed enhanced oil recovery processes with improved environmental and economic performance. More specifically, the displacement of organic wax phase (n-octacosane) by imbibed heptane in porous silica is explored as a first step to studying the displacement of bitumen with solvent in porous media. The experimental measurement method, based on local speed of sound measurements, is validated, and governing mass transfer relationships are explored at a spatial resolution of ~ 200 μm. Impact and speed of diffusion are examined as models are fitted to the data, and orientation of the interface and nature of the porous medium are the main variables.

38. RAJAN PATEL

Polynomial-Chaos-Expansion based Metamodel for Computationally Efficient Data Assimilation in Closed-Loop Reservoir Management

Data from "smart oil fields" can be continuously assimilated in closed-loop reservoir management (CLRM) to estimate unknown reservoir parameters. However, millions of simulation runs may be required in the process. In this study, computationally efficient and accurate, polynomial chaos expansion (PCE) based metamodel is proposed. The model parameterizes the unknown parameters and uses probabilistic collocation method to compute PCE coefficients. Instead of commercial reservoir simulator, PCE metamodel is used with Ensemble Kalman Filter (EnKF) and Markov chain Monte Carlo (MCMC) to estimate unknown parameters. A case study is performed using 3D field-scale model of a steam-assisted gravity drainage (SAGD) reservoir located in northern Alberta, Canada. Results depict that MCMC outperforms EnKF by providing better mean/variance estimates of unknown variables. Also, computational cost is reduced by two orders of magnitude us-

ing PCE metamodel. Practical implications of the proposed metamodel will be consequential in designing accurate and computationally efficient CLRM workflows.

HEAVY OIL - NON-AQUEOUS RECOVERY

39. MONIR HOSSEINI ANVARI

Wettability of Kaolinite Surfaces with Water-Cyclohexane Mixture: A Molecular Dynamics Study

There exists environmental and financial urge for recovery of the used solvent in the non-aqueous extraction of bitumen, which extensively depends on the strength of interactions between the clay surface and the liquid phase. We investigated wettability of the Kaolinite surfaces in the presence of cyclohexane at an atomistic level. The systems contained different number of water and cyclohexane molecules confined between an octahedral and a tetrahedral kaolinite surface. Formation of water bridge(s) between the two surfaces and wetting of the octahedral sheet were observed in all the systems. However, wettability of the tetrahedral sheet was found to be dependent on the amount of water. With NaCl added to the systems, the tetrahedral sheet-water interaction was greatly enhanced. At the molarity of 1.0, two water multi-layers were formed near the two surfaces, with cyclohexane channeled between them. The reason was attributed to the potential strength of the two charged surfaces.

40. JING LIU

Removal of fine solids from bitumen by polymer flocculants during non-aqueous extraction of oil sands

Non-aqueous extraction (NAE) of oil sands has been considered as an alternative technology to the conventional water-based extraction to decrease fresh water usage and avoid tailings issues. However, the significant amounts of fine solids left in the NAE bitumen make the product unsuitable for downstream operations. Surface characterization and surface force measurements demonstrate that the steric interaction among bitumen-adsorbed fine solids plays a dominant role in stabilizing these fine solids in the bitumen-solvent mixture. Polymer flocculants have been applied to bridge and flocculate the fine solids to clean up the NAE bitumen, via different interactions such as acid-base interactions, π-π stacking and intermolecular H-bonding attractions among polymers and solids coated with bitumen. This work provides useful information regarding the surface properties of the fine solids left in the bitumen from NAE process and the development of feasible approaches for removal of these fine solids.

41. QIANG CHEN

In-Situ Hot Filtration of Hydrothermally Upgraded Bitumen Product

The intimate association between hydrocarbon oil and mineral matrix is an important feature of unconventional petroleum resources, such as bitumen-bearing oil sands. In bitumen extraction from oil sands ore, contamination of bitumen oil by mineral solids is a nuisance. A new bitumen cleaning approach is proposed, which combines the hydrothermal treatment of bitumen-water or bitumen-solvent product, water/solvent separation by venting, and solids removal by in-situ hot filtration. A small-scale laboratory hydrothermal treatment using 500-mL Parr reactors was conducted at 300–420°C for 0–180 min. The results show that after the hydrothermal treatment followed by venting and filtration, the water content was reduced from 14 wt% to 0.03 wt%, and the fine solids content was reduced from 8 wt% to 0.08 wt% by hot filtration. In our future work, a pilot-scale study will be conducted using a 5.7-L thermal reactor to investigate the influence of hydrothermal treatment on the filtration behavior of both aqueously extracted bitumen froth and non-aqueously extracted bitumen supernatant.

42. LEI XIE

Understanding the Interfacial Behaviors and Molecular Interaction Mechanisms of Asphaltenes Using Experimental and Theoretical Methods

Asphaltenes adsorbed on oil/water/solid interfaces can significantly influence the interfacial properties, which play important roles in different oil production processes. In this work, the interfacial behaviors and molecular interaction mechanisms of asphaltenes in complex solvent conditions have been investigated using quantitative force measurements and molecular dynamic (MD) simulations. Drop probe atomic force microscopy (AFM) was applied to quantify the interaction forces between emulsion drops in the absence/presence of asphaltenes under different conditions. Interfacial tension measurements were conducted under different temperature and solvent conditions to investigate the adsorption process and interfacial behaviors of asphaltenes. Corresponding MD

simulations were performed to explore the mechanisms of asphaltenes' interfacial activities at atomistic resolution. This work provides useful insights into the fundamental understanding of the interfacial behaviors and molecular interaction mechanisms of asphaltenes at nanoscale in oil production.

LAND & WATER

43. STEPHANIE IBSEN

Invertebrate Indicators of Land Reclamation Success

Alberta's existing regulatory criteria for land reclamation focus on soil and vegetation. With a global focus on resilience and biodiversity there is debate about whether two-dimensional monitoring is sufficient for addressing reclamation trajectories and success and whether multi-trophic level indicators are needed. Reclamation monitoring rarely evaluates multiple ecosystem components, thus relationships among various ecosystem indicators are not fully understood. There are no methods for evaluating soil invertebrates as reclamation success indicators that do not require extensive knowledge and resources. There is a need for practical methods and a full assessment of reclamation indicators to determine if current criteria are adequate.

44. LEI ZHANG

Establishment of a semi-passive biofiltration process for the bio-removal of naphthenic acids from oil sands process water (OSPW)

Biofiltration has advantages such as robustness, simplicity of construction, and low energy input, which has been successfully used for water and wastewater remediation. In this study, a fixed-bed biofiltration system that utilized indigenous microorganisms was established for the treatment of OSPW. Ultra Performance Liquid Chromatography/High Resolution Mass Spectrometry (UPLC/HRMS) analysis showed that 21.8% of classical naphthenic acids (NAs) can be removed from raw OSPW after the circulation of raw OSPW through the biofilter for 8 times. Through ozonation pre-treatment with utilized ozone dose of 30 mg/L, 89.3% classical NAs in the ozonated OSPW can be removed by the biofiltration treatment. For raw OSPW, there was no NA removal after 4 circulation times of biofiltration. Regarding to ozonated OSPW, after the second 4 circulation times of biofiltration, the NAs from the ozonated OSPW can be further removed by 45.7%. The established mild-ozonation combined biofiltration process can efficiently remove NAs from OSPW.

45. ABDALLATIF ABDALRHMAN

Degradation of Naphthenic Acids (NAs) under Low-current Electro-oxidation on Graphite

Among the different constituents in OSPW, a group of aliphatic and alicyclic carboxylic acids known as naphthenic acids (NAs) are one of the main causes of concern because they are recalcitrant and can persist in the environment for many years. Electro-oxidation has emerged as promising process for the degradation of a variety of recalcitrant organic pollutants. The objective of this study was to investigate the effectiveness of low-current electro-oxidation for degrading NAs. The study focuses on evaluating the performance of inexpensive carbonaceous electrode materials under low energy operating conditions for degrading NAs and understanding the involved oxidation mechanisms. The results from this study show promising performance for electro-oxidation in degrading model NAs. Applying a low current density of 0.5 A/m2 by using low-cost graphite electrodes has resulted in removal rates of 67.0% and 83.1% for a model NA compound (cyclohexanoic acid; CHA) and commercial NA mixture, respectively.

46. RONGFU HUANG

Analytical and Toxicological Evaluation of Bioavailable Naphthenic Acids from OSPW Using Biomimetic Extraction - Solid Phase Microextraction

Biomimetic extraction via solid phase micro-extraction (BE-SPME) method has been reported to evaluate the ecotoxicity of polyaromatic hydrocarbons and commercial naphthenic acids (NAs) in samples. In this work, BE-SPME was applied to extract NAs from raw and ozonated oil sands process water (OSPW). The SPME fibres were analyzed using gas chromatography flame ionization detector (GC-FID) for semi-quantification of total organics, while atmospheric pressure gas chromatography time-of-flight mass spectrometry (APGC-TOF-MS) for compositional analysis of organic species. The samples were also examined using the Microtox assays at appropriate pH range. Generally, the BE-SPME analysis results follow the trend of Microtox results. For individual samples, the correlation of GC-FID and Microtox results is also related to the composition of organic species in raw and treated samples. The BE-SPME

method developed in this project could be applied to various OSPW reclamation/treatment options under FES for the evaluation of removal of bioavailable contaminants including NAs.

47. RUI QIN

The effect of oil sands process water inorganic matrix on the photodegradation of model naphthenic acids

Oil sands process water (OSPW) is a complex matrix containing inorganic and organic compounds. The main objective of this study was to investigate the effect of OSPW inorganic matrix (IM) on the photodegradation of the organic contaminants. To achieve it, OSPW inorganic fraction was obtained by removing the organic fraction with activated carbon adsorption. A laboratory scale photolytic process was developed using medium pressure Hg- lamp and applied with model naphthenic acids (NAs) spiked in buffer or OSPW inorganic solution. After UV exposure, NAs in OSPW inorganic solution were degraded with time, while no degradation was observed in buffer. This indicates that OSPW inorganic matrix accelerated the photodegradation of NAs. It presumably attributes to the generation of radicals or higher photoactive metals-NAs complex with the presence of OSPW IM under UV exposure. More experiments will be conducted to clarify the model NAs photodegradation mechanism with the presence of OSPW IM.

48. MINGYU LI

Industrial Applications of Cellulose Nanofibers for Water Reclamation

The industrial process water containing toxic dissolved organics and inorganics cannot be discharged directly to the environment. Using low cost adsorbents, which could be produced at large scale and with abilities to selectively remove the target pollutant, will be an economic and efficient approach for water reclamation. In the present study, carboxylate group bearing nano-cellulose fibrils (TEMPO-CNF) was prepared in order to adsorb copper from contaminated water. The Cu(II) adsorption from synthetic water by TEMPO-CNF were tested. The equilibrium reached within 2 min and the removal ratio was more than 98% under initial Cu(II) concentration of 2 ppm. The adsorption capacity decreased with the increase of solution ionic strength. Nevertheless, in 30 mM NaCl and 20 ppm Cu(II) solution (with similar ionic strength to oil sands process water), the Cu(II) adsorption capacity was still 60% of that obtained in 20 ppm Cu(II) solution with no NaCl added.

49. SHANDRA PANDEY

Behavioral Success Indicators (BSIs): A Review and Application

The objective of our project is to review and synthesize the organizations and management theory (OMT) literature on behavioral success indicators in order to develop potential measurement schemes for local energy land and water reclamation projects. Through undirected and directed search and review, we have identified the regulatory, audit, stakeholder and community consensus approaches to BSIs. We have isolated some key components from each and are constructing and testing our own synthetic framework. As part of our test, we are examining current critical values for land and water reclamation, and, as another part, we are designing an experiment to solicit feedback from Alberta community stakeholders about local passive absorption wetland design.

50. CHELSEA BENALLY

Use of carbon xerogel for adsorption of organic material in oil sands process water

This research demonstrated that a mesoporous carbonaceous material (carbon xerogel) can successfully be used to adsorb persistent organic contaminants from oil sands process water (OSPW). Of the two different types of carbon xerogel (CX) used, CX made at pH 5.5 removed a greater amount of acid-extractable fraction (AEF) than CX made at pH 6.9. For a 3 g/L dose of CX 5.5, the equilibrium adsorption capacity was found to be 15 mg AEF/g CX5.5 and 7.8 mg NAs/g CX5.5. After 24 hours of adsorption, 74.6% of AEF and 88.8% of total classical naphthenic acids (NAs) were removed. Adsorption of AEF and total classical NAs onto CX5.5 followed pseudo-second order kinetics. With respect to diffusion of AEF and NAs, there were three distinct regions: bulk diffusion, film diffusion and pore diffusion. The rate limiting step in all cases analyzed was pore diffusion.

NON-ELECTRIC INFRASTRUCTURE

51. YAJIE HAO

Fuzzy Sets and AHP to Model Group Decision Making for Energy Infrastructure Risks

Aimed at the improvement and optimization of the performance of available energy resources, risk factors have to be carefully identified, assessed, and quantified. This assessment is inherently associated with problems of decision-making, in which three important facets have to be taken into account: (i) multiple criteria when evaluating various alternatives, (ii) uncertainty originating from the complexity of the problem and its multifaceted nature, and (iii) presence of a group of decision-makers whose inputs are to be reconciled. These factors imply that the decision-making problem falls under the category of multicriteria group decision-making. Its formulation requires the optimization (maximization) of the consistency of individual assessments being provided by decision-makers, as well as the maximization of consensus established among a set of individual rankings. To address these challenges, in the formulation of the problem and its solution, we focus on the concepts of fuzzy sets and the Analytic Hierarchy Process (AHP).

52. EMAD MOHAMED

Development of framework for performance assessment and risk analysis during construction and maintenance of non-electrical infrastructure for energy

Construction and maintenance of long-life energy infrastructure assets are associated with unanticipated risks (e.g., weather-related challenges, unproven technology, and unknown stakeholder interactions), which create uncertainty during project planning and execution. Uninformed decisions made in response to such risks can lead projects to deviate from objectives, resulting in time and cost overruns, safety issues, quality deficiencies, and technical problems. Here, an integrated approach for reducing project uncertainty through the identification and analysis of non-electrical infrastructure construction and maintenance-associated risks is proposed. Risks will be identified through literature review and survey of subject matter experts, and fuzzy logic and simulation models will be used to quantify the impact of risk factors on project outcomes. Results generated using the approach can be used to (i) improve contingency estimates and (ii) assist with the development of effective risk mitigation plans, in turn, increasing bid competitiveness and project performance, respectively.

53. WEIXUAN TANG

Health Index Development of an Engineering Asset

Engineering assets are used for energy generation and delivery. These assets include infrastructure assets such as transmission lines, pipelines, and transformers. They also include wind turbines and thermos power generation stations. All such assets require proper design, construction, operation, and maintenance. To maximize their effectiveness over their life-cycle, condition monitoring is often used and proper health indexes can be developed utilizing such condition monitoring data. In this study, we use gearbox as a target asset. A health index (HI) of wind turbine gearboxes (WTG) will be developed that integrates multiple features (e.g. vibration, acoustic emission, oil analysis, temperature monitoring, performance monitoring, etc.) to reflect the comprehensive health condition of a WTG. Optimized maintenance decisions may be made based on the HI of WTG.

54. SATHISHKUMAR NACHIMUTHU

Maintenance Decision-making Models for Cost Minimization of Offshore Wind Farms

Offshore Wind Farms (OWF) are in its stage of continual development over the past two decades to meet the future energy demands of the global population. Maintenance activities at OWFs are difficult and expensive because of the remote location and harsh marine environment of the wind farms. Both the short- and long-term maintenance decisions are very much affected by the uncertain weather and sea-state conditions at offshore wind farms. Long-term decisions include wind farm site selection, wind turbine array design, and offshore base construction. Short-term decisions include maintenance scheduling based on the weather forecast and resource allocation. Such maintenance decisions greatly influence the overall O&M costs and the cost of energy produced. Maintenance decision making at OWFs should consider operational, tactical and strategic scenarios with risks/uncertainties. In this research, we aim to develop more effective models for effective maintenance decision making under various uncertainties.

SOLAR

55. ALEXANDER GZYL

Classification of Half-Heusler Compounds through Machine Learning Approaches

Half-Heusler compounds form a large, versatile class of solids with cubic structures having many applications as thermoelectric materials, spintronic materials, superconductors, and topological insulators. Many half-Heusler compounds conform to a structural description that combines features of the more covalent zincblende-type (ZnS) and more ionic rocksalt-type (NaCl) structures. However, there are notable exceptions (such as MgAgAs, GdPtSb, and PdHoBi) that do not. We have applied machine-learning approaches (through a support vector machine model) to classify, verify, and predict half-Heusler compounds. The model is able to determine which element occupies tetrahedral vs. octahedral sites, distinguish between ternary compounds that are half-Heuslers and those that are not, and predict new examples of half-Heusler compounds.

56. SHENG ZENG

Exploiting Nanophotonics and Plasmonic Hot Electrons for the Production of Solar Fuels

Plasmonic hot electrons generated in Au, Cu or Ag nanoparticles (NPs) offer an unconventional route to perform sunlight-driven water-splitting and CO_2 photoreduction. The generation of hot electrons is not controlled by a semiconductor bandgap. Instead the yield and action of hot electrons is dependent on the interplay of a complex set of sequential & competing physical processes such as Landau damping, Drude electron scattering, electron-phonon coupling, strongly coupled electronic transitions, etc. We built new platforms to exploit hot electrons for photocatalysis that also benefit from photonic crystal mediated light trapping effects. Initial results for sunlight-driven water-splitting and CO_2 photoreduction are highly promising. While noble metals are expensive, the strong amplification of local electromagnetic fields by plasmonic NPs means that a very small quantity of noble metals might be sufficient to obtain a high photocatalytic performance. The Shankar Group is also looking into the noble metal-free plasmonic behavior of metallic ceramics. "

57. PAWAN KUMAR

2D C-N Semiconductors: Graphitic, Earth-Abundant Photocatalysts with Tunable Bandgaps

To function as an efficient and durable photocatalyst, a semiconductor nanomaterial has to have adequately long carrier lifetimes, be resilient to harsh chemical environments, resist catalyst poisoning or allow for easy regeneration, and harvest a broad spectrum of photons in sunlight, ranging from the ultraviolet to the near-infrared. In addition, large scale commercial deployment of photocatalysts requires the active materials to be non-toxic, earth abundant and easily processable. The single biggest problem facing the field of photocatalysis is that the aforementioned requirements conflict with each other for nearly every available semiconductor. In this context, graphitic 2D semiconductors containing a core of carbon and nitrogen atoms offer an exciting way forward, since members of this family have tunable bandgaps, are cheap, chemically resilient, and also have excellent electronic parameters. In the Shankar Lab, we have synthesized a variety of new C-N containing 2D semiconductors in the form of both bulk material (powders and films) and quantum dots. "

58. MINJIA HU

New Approaches to Functionalize Silicon to Expand the Toolbox for Solar Fuel Generation

Depletion of fossil fuels and increasing environmental concerns have triggered an urgent demand for sustainable alternative energy sources. Due to an abundant raw material supply and a nearly optimum bandgap for sunlight absorption, silicon-based light absorbers are being considered for solar energy conversion to solar fuels. Nano- and microcrystalline silicon-based light absorbers, in particular nanowire structures, are being functionalized with inorganic, organic, and bacterial catalysts for generation of hydrogen gas (H2), a clean-burning fuel. Exquisite control over surface chemistry is critical to enable efficient charge transfer, and to stabilize the interfaces for extended periods of time under demanding conditions. While silicon-carbon bond formation on silicon surfaces has been extensively studied, including by our group, the interfaces tend to be resistive, blocking charge transfer. We are therefore studying other atomic linkers to develop more electrochemically active interfaces, based upon chalcogenides, to develop new interfaces for solar fuel generation.

59. LAWRENCE ADUTWUM

Discovery of Noncentrosymmetric Ternary Compounds from Elemental Composition: A Machine-Learning Approach

The absence of an inversion centre in crystalline solids is an important prerequisite for many useful electrical and optical properties in materials applications such as piezoelectric and nonlinear optical devices. Solids with noncentrosymmetric structures are unusual, being outnumbered by centrosymmetric ones by a factor of 5. Current strategies to design new compounds that are likely to adopt noncentrosymmetric structures, such as the use of asymmetric building blocks, rely on intuition and trial-and-error. We have recently applied machine-learning approaches to predict the crystal structures of large classes of solids (AB, ABC, AB2C) prior to their synthesis. Here we extend these techniques to discover new noncentrosymmetric compounds based solely on their elemental compositions.

60. VIDYANSHU MISHRA

In Search of Coloured Intermetallics

Colour in metallic solids is an unusual property that has been prized since ancient times in jewellery applications. Among over 100,000 intermetallic compounds reported in the literature, only ~100 exhibit colour. Most coloured intermetallics crystallize in high-symmetry structures (CsCl- or Cu2MnAl-type), have relatively simple stoichiometries (1:1, 1:1:1, 1:1:2), and possess energy gaps along special directions in their electronic structures. Recently we have synthesized Cu2LiM (M = Ga, Al) compounds showing golden yellow and pink colours, and characterized them by X-ray diffraction and solid-state NMR spectroscopy. Expanding on these efforts to discover other candidates for coloured intermetallics, we are now systematically evaluating the detailed electronic structures of many compounds to identify the common features that are likely to give rise to colour.

61. EHSAN VAHIDZADEH

CO_2 reduction performance of TiO2 nanotube-based heterojunction photocatalysts

Nanostructured heterojunctions consisting of TiO2 nanotubes (TNTs) and noble metal nanoparticles (NPs) have been demonstrated to be excellent photocatalysts for the sunlight-driven, vapor-phase transformation of CO_2 into methane. Key scientific questions in this field are : (i) What is the nature of the band alignment between TiO2 and noble metal in these heterojunctions ? (ii) Do any of these heterojunctions harvest visible light ? and (iii) What is the effect of phase and morphology on the CO_2 reduction performance? The Shankar Group has made progress toward answering each of the above questions. We measured the electronic band alignment in heterojunctions of TNTs with different NPs, and also studied the resulting CO_2 reduction performance. Heterojunctions containing copper species were found to harvest visible light through the Interfacial Charge Transfer (IFCT) mechanism. Anatase-phase nanotubes with circular cross-sections and rutile-phase nanotubes with square cross-sections were also examined for CO_2 photoreduction.

62. YIANG GUO

Do Solar Panel Installers Respond to Peer Effects? Evidence from Arizona's Electricity Market

Abstract Peer effects are the social interactions among consumers that create spillover effects from the adoption of new products. In the solar photovoltaic (PV) panel industry, the peer effects are particularly interesting for solar panel installers and policy makers as they can potentially be used to increase the adoption rate of solar panels in certain regions. This paper utilizes the discontinuity of consumer demand brought about by exclusive territories of utility companies in Arizona. In addition, it leverages the fact that one of the Arizona's largest utility companies, Salt River Project, significantly lowered its compensation rate for solar panels in February 2015, which caused a drastic negative demand shock within its territory. By testing whether bordered regions would have lower solar panel installations as compared to internal regions, this paper investigates how solar panel installers will react to peer effects.

SYSTEM WIDE

63. TANVEER HASSAN MEHEDI

Life Cycle Assessment of Energy System Transitions: the case of solar energy in Alberta

Solar energy has been gaining interest among the stakeholders in Alberta as the province has the highest annual sunlight in Canada. Although solar photovoltaic panels are usually considered as a safe and reliable source of electricity with minimal greenhouse gas emissions, the impacts from other life cycle stages such as the resource extraction, main com-

ponents manufacturing and transportation are considerable. Around 60% of the solar photovoltaic panels used in Alberta are manufactured in China, where carbon-intensive fuels are used. In addition, the transportation also contributes hugely to the overall greenhouse gas emissions. The main purpose of this research is to perform a comprehensive life cycle assessment to evaluate the economy-wide and the global impacts of solar-based renewable energy in Alberta. The results obtained through this project will help energy policymakers to identify the environmental hotspots in the solar energy pathways for Canada specific scenarios and take action accordingly.

64. A. OLUFEMI ONI

Environmental and techno-economic assessments of the new bitumen extraction technologies

The demand for lower cost, energy consumption, emissions, and water use, are the key drives that promote the development of sustainable bitumen extraction technologies. Various extraction technologies have been proposed to offer cleaner operations relative to the current processes. However, life cycle thinking based environmental and techno-economic assessments of these processes are required to ascertain their sustainability. There is sparsity of research examining the environmental and economic impact of these technologies. This research study is aimed to fill these gaps. The aim of this study is to provide a holistic assessment of the new bitumen extraction technologies for cleaner and efficient operations. Each technology will be developed using data intensive bottom-up life cycle and techno-economic assessments. A comparative analysis of the cost, energy consumption, emissions, and water use associated with each technology will be provided. This research work will provide Canada specific comprehensive baseline data for the oil and gas industries and policy makers.

65. ESKINDER GEMECHU

A framework to assess the sustainability of technologies under future energy system

Technologies under future energy system are acknowledged as the mitigation options to achieve the 2oC climate change goal of the Paris Agreement. However, there are several issues that need to be addressed for their deployment. These are: the availability of primary energy sources in a particular jurisdiction, the alternative pathways to convert each primary energy to secondary energy, the environmental, economic and social impacts associated with each energy conversion pathway. Aiming to answer those questions, this research attempts to develop a general framework to evaluate and compare future technologies based on their environmental, economic, and social performances. Life cycle sustainability assessment that incorporates the environmental-life cycle, techno-economic, and social implications will be the main methodological ground to be applied. The cost of production, greenhouse gas emissions, job creation, land use and water footprint are some of the relevant metrics that are used as a base for comparison.

66. DIEGO CHIAPPORI

Development and Application of GCAM-Canada Model for Future Energy Scenario Analysis

Integrated Assessment Models (IAM) describe key human activities associated with water, food and energy provision, their effects on the environment, and some of the corresponding feedback effects on human societies. This research project focuses on improving the representation of Canadian energy supply and demand, as well as an understanding of energy and environmental policy options and trade-offs, using a prominent IAM, called GCAM (the Global Change Assessment Model). GCAM has been successfully used by a variety of international agencies and nations in recent years to provide insight into economically viable and socially acceptable energy pathways to achieve desirable goals. In the longer term, a new model, GCAM-Canada, will be developed through this project to provide a decision support tool for evaluation of pathways to environmental sustainability, assessment of energy production options and emission reduction plans, and evaluation of climate change mitigation options in a single, well-established and consistent modelling framework.

WIND

67. TONG SHI

Study of Sub-Synchronous Resonance in Wind Farms

As one of the low cost renewable energy based power generation, wind power has gained increasing popularity in the past decade, leading to a large quantity of operational and under-construction wind farms (WFs) around the world. However, the large-scale integration WFs in the existing transmission and distribution networks has brought some challenges

as well. Particularly, the sub-synchronous resonance (SSR) oscillations have been observed in many WFs. These oscillations could cause damage to equipment in WFs and also affect the surrounding grid especially when there is grid compensation devices, FACTS (flexible AC transmission system) and HVDC (high voltage DC) systems. Therefore, this study focuses on the causes and solutions for SSR which are crucial for reliable WF operations and grid integrations.

68. BORIS ORTEGA MORENO

Analyzing the Effects of Increased Wind Generation Capacity in Alberta's Electricity Market: The Role of Firm-Ownership

This paper analyzes the effects of wind energy ownership in Alberta's electricity market. Heterogeneity among firms regarding cost functions and market shares may lead to different motivations to acquire wind generation capacity. The main focus of the analysis is to forecast the responses of firms to different allocations of wind electricity generation. Among others, these responses include changes in carbon emissions and equilibrium quantities and prices bid by the firms. Based on this information, it is possible to predict the effects on the composition of the energy sources used to provide electricity in the region, which, according to Alberta's Renewable Electricity Program objectives, is expected to move from coal-intensive towards green energy. The analysis is based on a modified version of the model used by Brown, Eckert and Eckert (forthcoming) that accounts for the new features of the market.

69. MIREILLE TADIE

Review of Microgrid Renewables Projects in Northern Canada

A review of past renewable energy projects in microgrid communities in Northern Canada is presented. The objective is to inform the proposed efforts in FES Wind Microgrid research in development of planning and design of wind projects for off-grid communities in Canada. The work shows that some efforts have been made for implementing wind power in off grid applications in Canada, generally with the effort to reduce reliance on fossil fuel powered generators. Success of such projects has been mixed and experience indicates that a systematic approach to renewable energy implementation must be adopted. This means design should include consideration of combined systems as well as community and logistic concerns which affect the long term viability and reliability of systems other than fossil fuel generators.

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