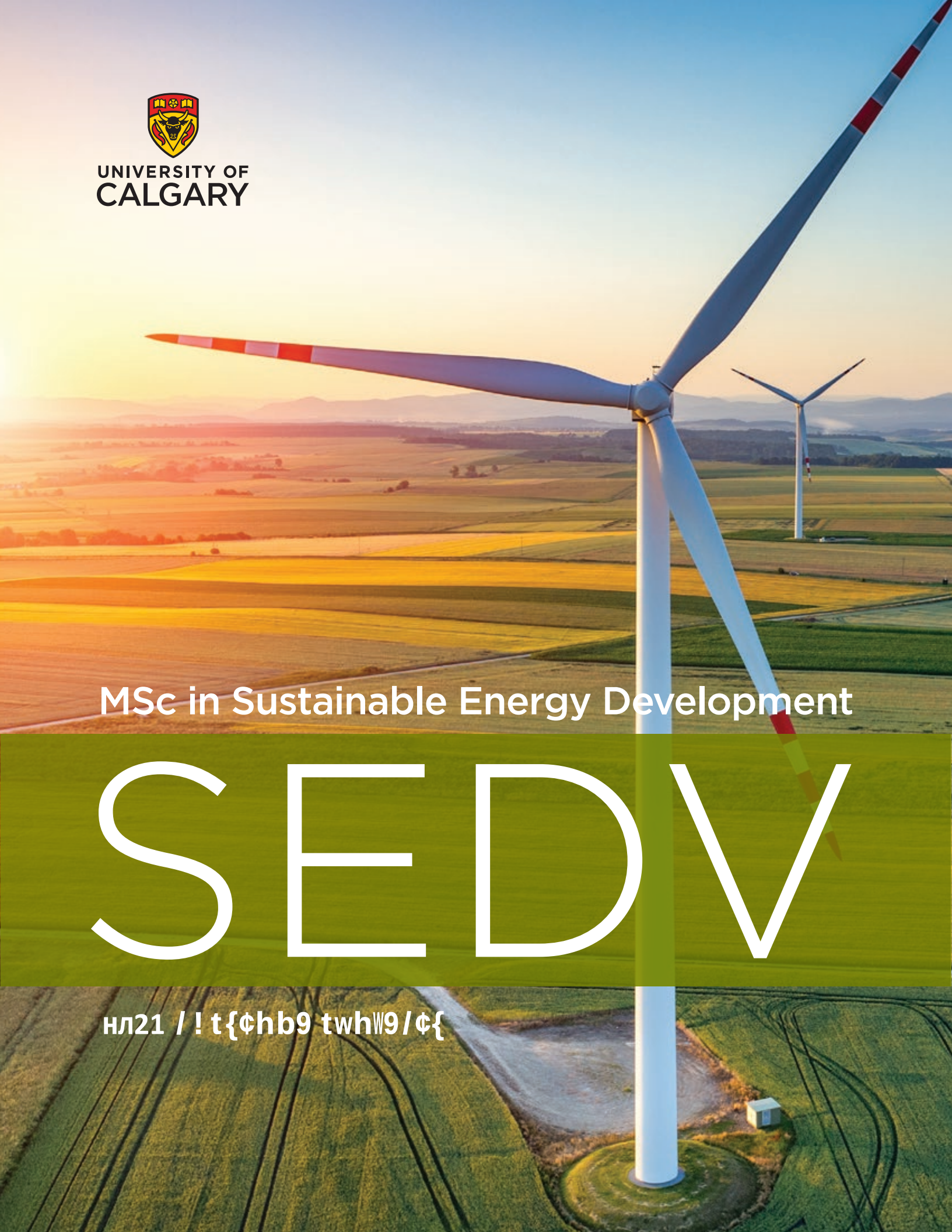

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2021 CAPSTONE PROJECTS

Algae Cultivation and Hydrogen Production from the Waste Streams of Electricity Generation

Brendan Struthers

To reduce greenhouse gas emissions (GHGs) and preserve freshwater resources, this study assessed the techno-economic feasibility of utilizing waste streams from natural gas combined cycle (NGCC) power plants to cultivate algae, reuse process waters, and produce hydrogen via hydrothermal gasification (HTG) of algae biomass. Algae cultivation trials indicated that Chlorella vulgaris can be grown in NGCC wastewaters and that the effluent is suitable for industrial reuse. Aspen Plus process simulations showed that the HTG of algae biomass is not economically competitive and that HTG methane emissions must be abated to enable low-carbon hydrogen production. A feasibility analysis of an NGCC-integrated algae cultivation-gasification system (ACGS) concluded that it would be challenging to implement the ACGS due to the high capital and operating costs of the current technology. Further investigation of algae-treated water for NGCC applications and the optimization of HTG processes is recommended to identify a sustainable model for ACGS implementation.

Business Models to Successfully Implement Clean Cooking Technologies in Tanzania

Aaraby Mohanathas

Approximately 94% of Tanzania's population uses some form of a traditional cooking fuel source, such as biomass or charcoal, on a daily basis to cook. These traditional fuel sources are environmentally harmful and lead to health problems in women and children. Tanzania is striving to transition into a clean economy, and the widespread implementation of clean cooking technologies is an imperative part of the transition. In Tanzanian culture women are responsible for cooking, therefore, this research reaches out to Tanzanian women to understand what support they need in order to transition into using clean cooking technologies. This research finds that Tanzanian women are willing to use clean cooking technologies but are unable to due to the price and lack of awareness on the benefits of using them. To eliminate these barriers, NGOs are encouraged adopt the IDCOL model + PAYGo model and provide Tanzanian women jobs to penetrate the rural markets as saleswomen and business owners.

Carbon Policies in Canada: Implications for Biomass District Energy Systems

Kayla Marlene Brehon

This study examines the impact of carbon policies on the implementation of biomass district energy (DE) systems within Canada. DE systems offer an energy efficient approach to providing heating, cooling, domestic hot water and sometimes electricity to residential or commercial buildings. Biomass and wood biomass is examined as an affordable fuel option for the DE systems. To reduce greenhouse gas (GHG) emissions, biomass DE systems can offer an affordable and stable option. This study examines how three systems across Canada are impacted by fuel charges or large emitter incentives and compares that to if they used only the fossil fuel most used in the province the system is located. It was determined by this paper that carbon policies increase these systems competitiveness in most circumstances. However, a dramatic increase in the cost for wood biomass or a drop in fossil fuel prices could render some systems economically inviable.

Cultural, Social, and Environmental Factors in Implementing Clean Cooking Technologies in Tanzania

Danielle Zezulka

After 40 years of attempting to implement cleaner cooking technologies (Batchelor et al, 2019), successes have been infrequent, leaving approximately 2.8 billion people (IRENA, 2020) to spend hours gathering biofuel and enduring smoke-related harm due to cooking with fire. Despite the years of research examining reasons for the failures, there do not appear to be sufficient studies of the social, cultural, or environmental factors to be able to predict the success or failure of a given project. By researching previous projects, the cooking culture and energy deficits of Tanzania, and various solar cooking technologies, and by talking with the diaspora Tanzanian community, on-land Tanzanians, and NGOs, conclusions about the readiness of Tanzanian culture and people to accept clean cooking technologies were developed. The results show that microgrids in combination with EPCs are the most viable options for Tanzania.

Enersion Tri-Generation System: Applications, Sizing, and Economics

Eric Swayze

Enersion Inc. has developed a proprietary Tri-Generation system which can provide electricity, heating, and cooling for buildings. Information about the economic and environmental viability of such a system is understandably lacking. This work provides recommendations to Enersion Inc. regarding some potential building types and locations where their Tri-Generation system may be advantageous. Publicly available software and building models, along with one author-created model, were used to generate energy supply and demand data, which were then compared to each other, to utility rates, and to utility grid greenhouse gas emissions. It was found that hospitals, vertical farms, and mid-rise apartments in California were the most reasonable fits for solar-based Tri-Generation systems while hospitals, vertical farms, and secondary schools in Ontario were the most reasonable fits for natural gas-based Tri-Generation systems. Many achieved payback in less than 10 years. These recommendations may be used by Enersion in their marketing and business strategy.

Evolution of ESG Reporting within the Canadian Energy Industry

Maren Blair

Sustainability reporting for non-financial disclosure is not new, but recently environmental, social, governance (ESG) publications have become critical to attracting investors. In particular, industry-specific disclosures on topics such as greenhouse gas (GHG) emissions have become more prevalent as environment, climate change, and social consciousness are highlighted in mainstream media. In addition, investors are calling for standardization of ESG disclosure by the Canadian energy industry. In this report, I consider the progress made in ESG framework standardization and the type and accuracy of GHG disclosures by conducting a content analysis of 26 Canadian energy company ESG reports. I find that the industry has shown an increase in its due diligence in many aspects of ESG reporting, including the disclosure of Scope 1 and 2 emissions footprints and intensities. Improvements in reporting are needed for metrics such as Scope 3 emissions, GHG quantification methodologies and data verification, and emission reduction strategies.

Feasibility of Hydrogen Production From Municipal Solid Waste Gasification in Alberta

Behnaz Afsahi LaFrenz

To reduce greenhouse gas emissions (GHGs) and divert municipal solid waste (MSW) from landfills, this study assessed the techno-economic feasibility of biomass and MSW gasification to produce hydrogen as a clean fuel for local transportation in Alberta. The results of biomass and MSW gasification indicated this process, coupled with carbon sequestration, can economically produce hydrogen with very low GHG emissions at costs currently below that of renewables paired with electrolysis. The calculated minimum hydrogen selling price (MHSP) from biomass gasification ranges from ~1.9 – 3.0 $/kg. The preliminary estimates for MSW gasification yield a MHSP of ~1.6 – 2.5 $/kg. Hydrogen production as transportation fuel in Alberta from biomass and MSW is both technically and economically feasible. Especially for MSW, as there are gate fees to incentivize diversion of wastes from landfill as a negative value waste stream. Further investigation of MSW gasification and the impact of feed variability on hydrogen yield is recommended.

Feasibility of Utilizing On-Site Solar Thermal Energy Production Plus Thermal Energy Storage for EV Charging

Ian Choveaux

This paper seeks to determine the feasibility of utilizing on-site concentrated solar power plus thermal energy storage to produce energy for electric vehicle charging in Medicine Hat, Alberta. A literature review outlines system specifications to determine the potential viability of a novel concentrated solar power generation technology through an assessment of the solar thermoelectricity via advanced latent heat storage (STEALS) system which utilizes miscibility gap alloys (MGAs) as the thermal energy storage component of the system. A comparative economic analysis that utilized the U.S. National Renewable Energy Lab's (NREL) System Advisor Model (SAM) to determine the levelized cost of energy (LCOE) and resultant feasibility of a project or system, found a solar photovoltaic plus STEALS system to have a lower LCOE than a solar photovoltaic plus battery energy storage system.

A Feasibility Study: Investigating Sustainable Building Practices and the Circular Economy in Modular Structures for Residential Use in Western Canada

Nick Cunningham

The building construction sector is responsible for significant consumption of natural resources, energy, and the production of waste. The increasing scarcity and costs of raw resources for buildings and their components has recently driven industry researchers to investigate alternative building practices. Shifting from linear to circular economies using innovative building concepts of modular construction have been previously identified for their combined potential to reduce inefficiencies, environmental impacts, and contribute towards achieving Sustainable Development Goals. The objective of this study is to investigate the technical and economic feasibility of converging circular business models with residential modular construction in Western Canada. Using an investigative and exploratory approach, the qualitative methods of this research determined that the potential opportunities of incorporating circular principles with modular homebuilding are outweighed by the existing barriers. These concluding findings indicated that the practical application of this circular business model was not currently considered to be feasible.

Feasibility Study of Solar Photovoltaics System at Abandoned Mine Tailings Sites

Jason Shim

The objective of my research study is to determine the feasibility of using solar photovoltaic (PV) - geomembrane technology to generate clean renewable energy at abandoned mine tailings sites. Commercial mining activities in the province of Nova Scotia have resulted in abandoned tailings sites over the years that contain significant concentrations of toxic substances that pose serious social and environmental problems. My research could provide a solution to remediation of abandoned mine tailings sites using solar PV - geomembrane technology to mitigate tailings contamination problems and generate renewable solar energy to reduce greenhouse gas emissions. The Victoria Junction Tailings Dam in Cape Breton, Nova Scotia was selected for this study. A techno - economic assessment of the mine tailings site was conducted using ArcGIS, RETScreen and SAM software. The study concluded that abandoned mine tailings sites can be utilized for installation of solar photovoltaic farms.

An Investigation of the United Nations Sendai Framework for Disaster Risk Reduction and Its Applicability to the Fort Chipewyan Community

Meagan Fong

Since disasters occur at a local level, it is important to assess community-based disaster risk management to ensure that the community can prevent and reduce new or existing risks. In response, the United Nations Sendai Framework for Disaster Risk Reduction (Sendai Framework) (2015-2030) was adopted to strengthen community resilience through disaster risk management. The research question that this project examines is: can the United Nations Sendai Framework build community resilience through improved disaster risk management, including climate change adaptation measures in Fort Chipewyan? This report will employ an extensive literature review to assess some of the environmental, technological, and man-made hazards in Fort Chipewyan, as well as provide a thorough description of lessons learned from the 2016 Horse River wildfire, and current policies, legislations, and regulations in place. This will allow the report to determine the benefits, and challenges to implementing the Sendai Framework within Fort Chipewyan's emergency management programs.

Life Cycle Impacts of Direct Lithium Extraction from Canadian Brine Deposits

Matthew Dreis

The global demand for lithium is expected to increase over 250% by 2030, predominantly driven by the increased production of lithium-ion batteries. Consequently, concerns regarding lithium supply and the associated environmental impacts have been raised. This has led to new developments in direct lithium extraction (DLE) technology to produce from unconventional reservoir and oilfield brines. This research conducts a life cycle assessment to evaluate the environmental performance of deploying DLE technology in western Canada. The analysis is based on a combination of literature, lab, and field-scale experimental data. Comparative to incumbent methods of production, the results suggest that DLE technology deployed in western Canada can reduce land occupation and freshwater consumption up to 99% and 96% respectively. Global warming impacts are particularly sensitive to power grid emissions intensity and chemical consumption, observed to vary depending on chemical production processes.

Microgrids: Advancing the Resilience of Canada's Future Energy System

Anwuri Becky Okoromah

The purpose of this research project was to determine the potential market for microgrids in Canada as well as the barriers and challenges associated with the development of remote microgrids. As Canada and the rest of the world shift away from fossil fuels and toward renewable sources of energy, remote Indigenous communities are often left out of the development process. Microgrids offer an opportunity for remote Indigenous communities to move from diesel dependence to renewable energy that is reliable and affordable. The research also examined the policies and incentives driving the growth of microgrids. These objectives were achieved through: (a) compilation of all Canadian microgrids into excel. b) a review of prior academic and non-academic literature on policies supporting renewable energy growth in remote communities. The key findings show that residential microgrids, remote ones, have the highest potential market segment in Canada.

The Potential for Small Modular Nuclear Reactors to Support the Hydrogen Economy

David Anthony

Small modular nuclear reactors (SMRs) offer the promise of firm, low-carbon power generation. Hydrogen gas is a proven energy carrier with storage potential. This research analyzes three of the latest SMR designs and two of the more current and emerging technologies for commercial hydrogen production. An analysis of the levelized cost of nuclear-based hydrogen production, and its demand in support of climate change mitigation, is complemented by a comparison of CO2-eq emissions between hydrogen produced from SMRs versus natural gas.

The Hydrogen Economy Evaluation Program (HEEP), developed by the International Atomic Energy Agency (IAEA), was used for the cost analysis. Techno-economic parameters included vendor-specific designs, costs, and operating periods in addition to discount and interest rates. The total mass of nuclear-based hydrogen required to curb global warming, and the subsequent CO2-eq emissions produced, were estimated from public data and previous life cycle studies of SMR and natural gas hydrogen production.

Potentials and Challenges of Advanced Biofuels for Long-haul Transports in Western Canada

Farhana Mustafa

Canada’s aim to achieve 30% below 2005 levels of greenhouse gas (GHG) emissions by 2030 calls for alternative fuel sources for heavy transports. Biofuels can play an important role in this area. Some companies have started to convert forestry and agricultural biomass into biocrudes through hydrothermal liquefaction (HTL). These biocrudes, such as Steeper Energy’s Hydrofaction® Oil, can be used as advanced biofuels after upgradation. This study conducts a literature review of potential GHG emission reductions of the production and usage of this biofuel compared to conventional transportation fuels and discusses these potentials in the policy context of Western Canada. The findings suggest that advanced biofuel is capable to reduce 60-80% of the GHG emissions. However, second-generation fuel price is higher than the fossil-based ones. Widespread adoption of these fuels in the long-haul transport is possible when provincial and federal government policies and regulations will be aligned to incentivize innovative technologies like HTL.

Research Gaps in Life-Cycle Assessments Concerning Pumped Hydroelectric and Utility-Scale Battery Energy Storage Systems (ESS): Establishing a Unifying Approach to ESS Comparison

Travis Taro Brookson

Electrical grid decarbonization is one pathway to reduce global greenhouse gas (GHG) emissions as traditional thermal power generation is replaced by renewable energy. The intermittent nature of wind and solar power require energy storage to deliver excess energy during times of low power production. Both pumped hydroelectric storage and utility-scale battery storage are common solutions for different grid applications to maintain reliability, and each have their unique associated environmental impacts. In this report, life-cycle assessment (LCA) is used to examine the environmental impacts of the two energy storage systems. The limited number of relevant and available LCA studies lack a consistent approach and this report highlights some of the ambiguities and limitations that are barriers to proper comparison of the storage options. Finally, methods to increase the rigour of future energy storage LCAs, including keeping pace with the industry evolution, are recommended.

Strategy to Become a Zero-waste Community at Varsity Courts Family Housing at the University of Calgary

Susana Moncada García

The excessive production of solid waste has caused severe environmental problems. Zero-waste initiatives are based on the circular economy model, aiming to recover and conserve resources, and reduce waste sent to landfills. The University of Calgary aims to divert 70% of its waste from the landfill by 2025. This capstone project seeks to develop intervention strategies to help Varsity Courts Family Housing residents to adopt zero-waste behaviours. Thus, this project aims to contribute to achieving the university's zero-waste goal. A survey was created to determine which factors from the extended Theory of Planned Behaviour influence the residents' behaviours to develop and implement interventions that promote zero-waste behaviours. Findings demonstrated that interventions should consider subjective norms, perceived behavioural control, and environmental awareness. The most effective interventions were brochures, videos, social media posts, and educational workshops. At the end of the project, small changes in the behaviour of the residents were observed.

Techno-Economic Assessment of Lithium Extraction From Flowback and Produced Water

Adam Leece

In the path towards decarbonization, rechargeable lithium-ion batteries are critical for the widespread adoption of electric vehicles and renewable energy storage systems. Alternative sources of lithium are being explored to satisfy the critical nature of this mineral. This study assessed the techno-economic feasibility of direct lithium extraction (DLE) from flowback and produced waters (FPW) of the Duvernay shale development near Fox Creek, Alberta. DLE utilizing ion-exchange sorbents was determined to be a viable option, with fluid pH, temperature, the presence of total suspended solids and organic carbon playing a critical role in extraction efficiencies. In the assessment of one Duvernay hydrocarbon processing facility, 15.4 tonnes of lithium could be extracted from the FPW per annum. The results indicate that lithium extraction and refining into battery-grade products are economically feasible at forecasted commodity prices. Further investigation into field testing DLE technology and the minimum scale of a lithium development is recommended.

Toward Zero Waste – A Study in Reducing and Managing Lab Waste

Gideon Choi

The linear waste management model (take-make-dispose) has led to consumption and production patterns that exceed Earth's sustainable capacity. Zero Waste philosophies emphasize the reduction of raw material usage, retention of value in manufactured products, and align with UNSDG 12 'Responsible Consumption and Production'. The University of Calgary's Zero Waste strategic plan aims to create a Zero Waste campus by 2030. One key challenge is addressing the high volume of non-hazardous lab waste, including unrecycled glass and plastic, discarded lab equipment, and contaminated mixed recycling. Qualitative methodologies, including an electronic survey, are used to create a best-practice guide for implementing sustainable lab activities. Behaviour change barriers related to cost and effort are discussed related to voluntary adoption of environmental behaviour through education, clear communication, commendations, and increased waste diversion options. Staged implementation can potentially offer quantitative metrics to measure future impacts of implementing sustainable lab activities.

Using Mapping Tools to Improve the Integration of Traditional Knowledge and Science in EIA: The Site C Clean Energy Project Case Study

Greg Tyszko

This study examines information provided by traditional knowledge and science studies that were sourced from the Site C Clean Energy Project EIS to develop a more complete understanding of the impacts on watersheds, species of interest and cumulative effects of energy development on Indigenous communities. Impact maps were created and compared, using Geographical Information Systems, to determine what species and watersheds were impacted and cumulative effects maps were made to display the impacts of energy development on the area over time. The maps reveal that traditional knowledge and science have more in common than they differ, and the cumulative effects of energy development have significantly impacted Indigenous people's ability to live their traditional way of life. The study recommends a more collaborative approach between the two knowledge systems to share data and work cooperatively to ensure the impacts on valued environmental components are understood for future development.

Utilizing Renewable Hydrogen for Mine Haul Vehicles in Canada: A Techno Economic Assessment

Christopher Wallace

To reduce emissions from diesel-fuelled mine-haul fleets in Canada, hydrogen has been considered a viable alternative. However, emissions from electrolysis can increase depending on the carbon dioxide (CO2) intensity of the electrical source. This study found that total emissions can be reduced by 50% with grid-connected electrolysis and up to 90% when connected to a renewable energy source such as a wind turbine. The study results indicate that the current cost of ownership for fuel-cell electric vehicles (FCEVs) and hydrogen production from wind energy is approximately 18%-30% higher than diesel fuel. As technology learnings increase, utilizing hydrogen in mine trucks will be economically viable to diesel-fueled mine-haul fleets as future costs are projected to drop by 2030. This techno-economic prefeasibility study investigates the amount of emissions reduction and cost-savings from diesel-fuelled mine-haul fleets by utilizing electrolysis from either grid-electricity or wind-energy in FCEVs within the Canadian mining industry.

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