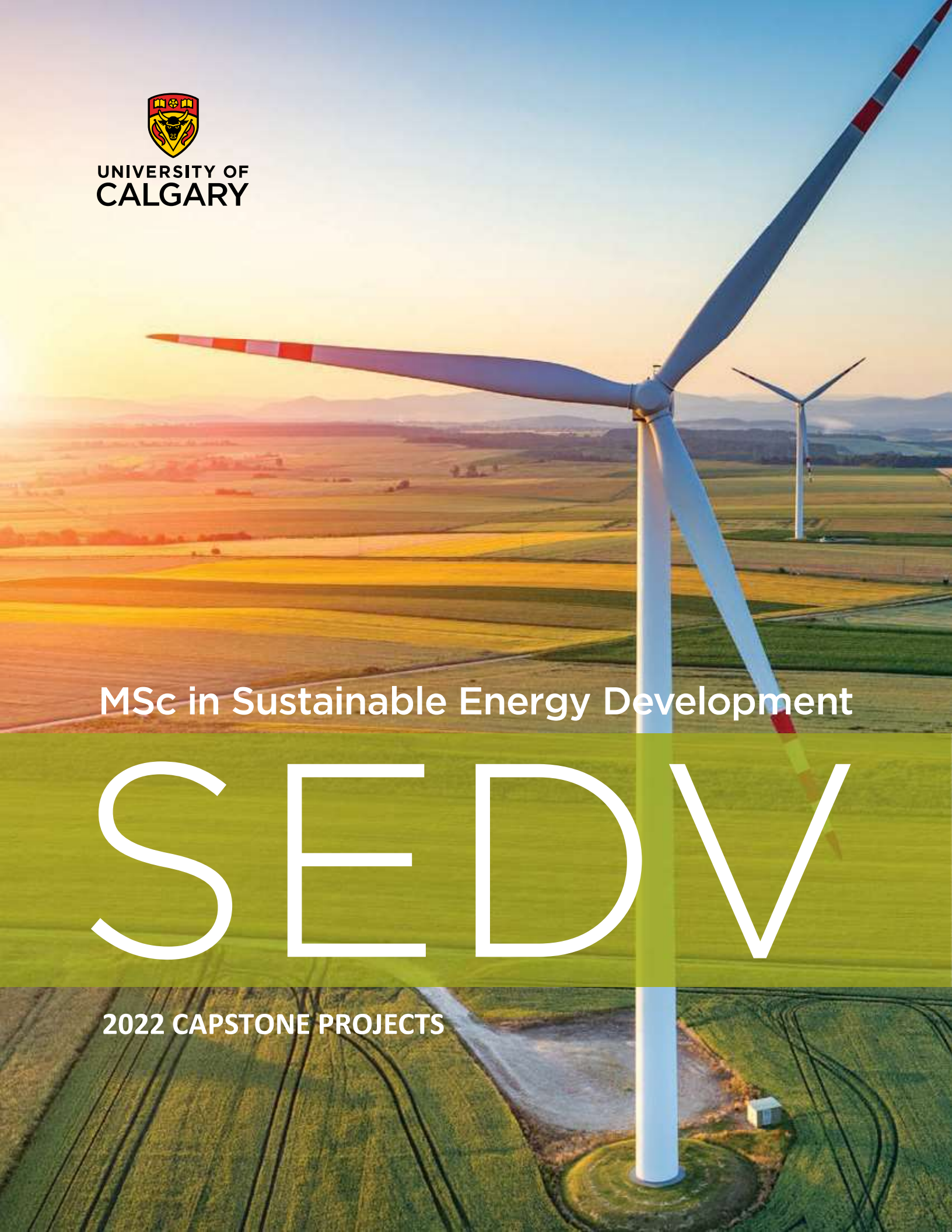

UNIVERSITY OF CALGARY

MSc in Sustainable Energy Development

SEDV

2022 CAPSTONE PROJECTS

2022 CAPSTONE PROJECT ABSTRACTS

Analysis of Standards and Certification Protocols for Verifying Recycled Content in Plastic Products
Alexander Emanuel Diaz Sotil

This study focused on analyzing and evaluating existing and in development regulations, in anticipation for this regulation and considering the lack of harmonization around plastic recycling in Canada, and the way that reciChain can support with compliance to those regulations. It also included the evaluation of the EPR considerations in different provinces in Canada, the study cases that are related to reciChain and how OECD countries are managing their plastic waste. These aspects were essential to answer the research question: how does reciChain fit within existing and in development North American and international standards and certification protocols for verifying recycled content in plastic products, and how it can support with the implementation of effective certification programs? It is important to consider that only 6% of plastics are recycled in Canada, and 85% of the plastic waste generated annually ends up in landfills.

Assessing Risks in Academic Labs: Uncertainties and Opportunities
Dalila Cristina Caparroz

An institution as large as the University of Calgary (U of C) consists of more than 1000 laboratories with varying risks. The Environment, Health, and Safety officers cannot audit every laboratory regularly due to limited personnel. Moreover, the academic setting presents unique challenges not encountered in the industrial setting. Research activities are constantly progressing, new hazards are introduced, and members with different experiences rotate through the laboratories. This project proposes a methodology to assess and rank the various chemical hazards in the laboratories. A tool for analyzing the chemical risk levels present at each laboratory was developed, enabling the University to identify laboratories with higher levels of chemical hazards and prioritize them for audit. The CSLs and Hazard Codes matrix was created using an in-depth literature review, the Globally Harmonized System of Classification and Labelling of Chemicals, and the support of the safety specialists working at the University.

Assessment of Indigenous Perspectives Embodied in Sustainability Reporting and ESG Disclosure Practices of Canadian Exploration and Production Companies
Kimberly Markvoort

Environmental, social and governance (ESG) reporting plays an increasingly important role in Canadian business. Indigenous rights are emerging as key disclosure criterion for ESG reporting in Canada's energy sector. A matrix of potential ESG performance metrics was developed of known concepts and key words associated with Indigenous Peoples' rights and ways of knowing. The matrix was applied to qualitative assessments of 47 sustainability reports published between 2010 and 2020 by the largest publicly traded Canadian oil and gas companies. Indigenous engagement as a financially material ESG factor evolved over time with emphasis on relationship building, consultation, capacity building, indigenous procurement initiatives and partnerships. The 2020 sustainability reports had dedicated sections for indigenous engagement and community investment. Absence of actionable, measureable steps to achieve indigenous engagement targets reflects that sustainability reports are used to highlight corporate achievements rather than report on corporations' sustainability management and ESG performance shortcomings.

Climate Adaptation in the North: Building Resilient Energy and Transportation Systems for Communities
Mary Margret

With the climate warming at an alarming rate in the Arctic, communities of the Northwest Territories (NWT) require holistic, mindful, and strategic adaptation programs to help them stay resilient in the face of severe risks impacting their already vulnerable socioeconomic conditions. This project formulates an inventory comprising of climate adaptation strategies ideated, developed, or implemented by Indigenous communities across a few selected jurisdictions in the Arctic that could potentially pose as solutions for the climate risks faced by the NWT. These community-based adaptation strategies involve partnerships between Indigenous communities, the scientific community, government bodies, and other organizations and directly or indirectly address the disruption of energy and transport systems in the NWT as a result of permafrost thaw, flooding, and wildfires. The inventory aims to provide functioning examples of strategies that have worked in other Arctic jurisdictions to be used as potential adaptation strategies within the communities of the NWT.

Commercialization of Lithium Titanate Batteries
Maryam Ghamami

Battery-operated products are increasing exponentially due to energy transition and improvements in battery technology. Therefore, using safe and efficient batteries with a longer lifetime, less environmental emissions, and higher power capacity benefits the environment, economy, and energy sectors. Lead-acid and Lithium-ion (Li-ion) are currently utilized 1) as starter batteries, 2) as a backup for renewable energies, and 3) as mobile hybrid energy storage. The main drawback of these batteries is reduced efficiencies in cold weather. The lithium titanate oxide (LTO) battery can operate in freezing climates and has a longer life cycle; thus, its use is recommended in applications where the weather is cold. The market trend shows that using LTO batteries is a solution to meet the battery demand in 2030. The only problem is the LTO batteries' cost but applying leasing options and considering total-lifetime cost makes them the best choice for infrastructures.

Commercialization Potential of Industry-Specific Methane Bio-Filters (MBFs)
Devika Subash

Methane Bio-Filters (MBFs) use methanotrophic bacteria to convert methane (CH4), a key greenhouse gas, to less polluting end products. MBFs are designed to treat point-source low volume CH4 emissions as an alternative to flaring and venting activities. This study evaluates six active MBF pilot installations in the oil & gas, agriculture, and waste industries in Western Canada to explore its commercialization potential. This work draws conclusions from research on MBF technical, process and market evaluations. As per the methodology used, economics aspect is the knowledge gap identified. Hence, my research question is whether this technology is economically feasible based on financial analysis of pilot installations? Research concluded economic viability at $10-$16/tCO2e for evaluated designs. The MBF adoption by industries are dependent on the costs and benefits of this technology. This work is multi-disciplinary focusing on energy, environment and economic dimensions. MBFs shows promise, as it grows to shed its weakness with each pilot project.

Deep Energy Retrofits in Housing for Low Income Household in BC and Manitoba: An Opportunity for Climate Mitigation and Social Equity

Godwin Ezinkwo

The low-income and vulnerable populations in Canada often live in social housing buildings with poor energy and environmental indoor performance. Many social housing buildings in Canada need major repairs and would also benefit from deep energy retrofits (DER) that could make them climate resilient, and safe for occupancy. The objective of this research was to investigate the GHG emissions reduction, as well as the energy and cost saving potential of different retrofit approaches in BC and Manitoba. I collected electricity and natural gas consumption data for 30 buildings in BC which were subsequently narrowed down to 6 building sites based on their location and type of retrofit. I also collected data for 2 buildings in Manitoba. One building received an interior insulating spray foam application, and the other, exterior spray foam. My study shows that different retrofit approaches executed in BC yielded 18% to 39% energy savings and 27% to 99% GHG emissions reduction as a result of the electrification of one or both end-use systems for space and water heating, as well as building envelope upgrade. Significant energy savings and GHG emissions reduction were also realized in the two Manitoba buildings where building envelope enhancements were executed including the installation of high efficiency heat recovery ventilation systems.

Eavor-Loop™ Geothermal for Combined Heat and Power at the University of Calgary: A Techno-Economic Analysis

Nicolas Barry-Hallee

A techno-economic feasibility analysis was conducted to determine the suitability of an Eavor-Loop™ closed-loop geothermal system from Eavor Technologies as a replacement for natural gas cogeneration of combined heat and power at the University of Calgary main campus in Calgary, Alberta. A base case comprised of the existing cogeneration system was compared to an Eavor-Loop™ study case over a 30-year analysis period. 30 °C/km geothermal gradient results showed that a 9 km total depth or greater Eavor-Loop™ system comprised of between 2 to 4 loops provided a lower LCOE, total cost of ownership, paid back over the base case between years 8 and 20, and avoided a lifetime 2.15 million tonnes of CO2-eq. Base case costs are dominated by the cost of fuel and the price of carbon. Overall economic feasibility of the Eavor-Loop™ system can be improved through reducing heat exchanger leg drilling costs and attaining competitive financing.

An Economic Assessment of Renewable Natural Gas (RNG) as a Potential Low Carbon Intensity Fuel Alternative Eligible Under Canada's Clean Fuel Regulations

Jordan Williams

The purpose of this project is to determine whether the production of renewable natural gas (RNG) using corn stover or dairy cow manure in Canada is economically feasible using a discounted cash flow analysis. Further, this work seeks to determine if there is sufficient, reliable feedstock to sustain desired production levels over the lifetime of a production facility. This project also evaluates the effect of Canada's newly introduced Clean Fuel Regulation (CFR) and CFR credit sales on the profitability of RNG production. This work calculates that the cost to generate a credit under the CFR using manure or stover based RNG production can be as low as $315 or more than $28,000 under unfavourable circumstances. This work provides better understanding of the economic challenges of RNG, showing that feedstock acquisition and transportation costs significantly impact a projects' ability to be profitable, leading to credit generation costs which are not competitive.

Evaluating Greenhouse Gas Reduction Programs for Natural Gas Pipelines
Timothy Smith

Natural gas plays an important role in heating homes and fueling industry now and for many years to come. Natural gas transmission pipelines are integral to ensuring natural gas is delivered to those homes and businesses that depend on it. The 113 compressor stations on these pipelines dispersed across western Canada are responsible for most of the 8 million tonnes of GHG emissions per year. Although technology exists to reduce the emissions at a single station, the implications of wide-spread compressor station decarbonization have not been well-studied. The research question, is a unique policy approach needed for decarbonization of natural gas pipelines, was investigated through a scenario analysis that assessed the cost-benefit of 3 scenarios. From the analysis it was determined that existing carbon pricing schemes are likely to be effective but could be optimized to better incentivize emissions reductions for natural gas transmission pipelines.

Feasibility of using pressure retarded osmosis (PRO) to replace diesel in Bella Coola British Columbia
Jessica Renee Owen

Can pressure retarded osmosis (PRO) reduce or eliminate diesel dependency in Bella Coola, British Columbia? This study looked into the possibility of using PRO to replace diesel in Bella Coola by analyzing the energy potential of six watersheds in the region, comparing the levelized cost of electricity (LCOE) of PRO to current diesel prices, and examining potential environmental impacts associated with PRO. Analysis showed that the most significant factor preventing PRO from being a viable option in Bella Coola and other markets is contributed to the high cost and poor efficiency of PRO membrane technology. While PRO technology may not currently be economically feasible for Bella Coola, with the introduction of the communities proposed hydroelectric facility in Nooklikonnik Creek, PRO could subsidize the remaining energy demand from diesel in the future with less environmental impacts than current systems.

Feasibility Study of Residential Cold Climate Air-Source Heat Pumps as a Sustainable Solution in Calgary, Alberta
Annelore Dietz Muñoz

Building electrification is being utilized to decarbonize the residential sector across the world. Canada has committed to becoming net-zero energy by 2050, with Alberta playing an essential part. According to the Alberta Government, the province plans to modify its electricity supply system to reduce carbon intensity significantly. Thus, this project aims to identify how these changes can create an opportunity for electrification in Alberta. Specifically, this research seeks to determine when and under what conditions installing ccASHPs on a townhouse in Calgary would make sense regarding energy consumption, GHG emissions, and costs. Compared with NGF with air-conditioning, ccASHPs consume less than 50% energy for heating, cooling, and DHW, showing improved environmental performance since 2023 or 2024, depending on the future grid scenario, but the economics are still a challenge. Current commitments and further federal and provincial incentives to electrification, energy efficiency, and cleaning the Alberta grid could change the economic prospect of ccASHPs in the future.

For Peat's Sake! Climate Change, Citizen Science, and the Northwest Territories
Coleen Newby

The Northwest Territories is experiencing global warming at a rate two to three times faster than the other areas of Canada (Environment and Natural Resources [ENR], n.d.-b). Canada has committed to address climate change, participate in the global low-carbon economy, and build resilience in Canada's most impacted communities. There is growing global concern regarding the pace at which frozen peat is thawing, and the potential for the release of carbon and other greenhouse gases into the atmosphere (Hugelius, 2020). The Northwest Territories peatlands are critical for mitigating the effects of climate change and preserving biodiversity. The purpose of this study is to identify a sustainable framework for community-based peatland environmental monitoring that engages Indigenous communities, embraces Traditional knowledge, and increases scientific literacy. Investigating a potential link between the economics of Sustainable Development Goals and project funding may prove to benefit the economic viability to sustain citizen science and conservation.

Formula 1: Race for Sustainable Air Transport
Sarah Grenon

This study assesses net zero CO2e technologies for air transport to determine which is the most cost-effective for use by Formula 1 by 2030. I examine four potential net zero technologies: voluntary carbon offsetting (VCO), sustainable aviation fuels (SAFs), electric aircraft, and hydrogen-powered aircraft. My analysis presents the feasibility, availability, economic risk, approval, and net zero potential of each technology and is based on a survey of academic, government, and industry literature. I found that VCOs and SAFs are technologically feasible and sufficiently available while electric aircraft and hydrogen-powered aircraft are not. The economic analysis reveals that purchasing VCOs is the most cost-effective option to reach net zero. However, Formula 1 has decided to employ SAFs instead of VCOs despite the higher costs, this is likely due to the value of the positive reputation gained from the use of SAFs relative to of VCOs.

Hydrogen and Ammonia Pathways Towards Net-Zero in the Northwest Territories
Zachary William Cunningham

Currently, the Northwest Territories (NWT) imports 89.3% of its energy in the form of fossil fuels to meet the demands of 45,132 people living in 33 communities. Due to this high fossil fuel usage, the NWT has per capita emissions 1.8x the Canadian average. To meet Canada's 2050 net-zero goal, there is a high need for a clean, robust, and resilient energy system in the NWT. This energy system analysis highlights the key sectors in the NWT that can be transitioned to zero-emission hydrogen and ammonia and determined the additional hydroelectric capacity that needs to be constructed to produce it. It was determined that by increasing the current hydroelectric capacity by 731 MW, enough electricity would be available to produce the hydrogen backbone of this energy system which provides a basis for a 100% reduction of fossil-based carbon dioxide (CO2) emissions when paired with increased electrification and drop-in biofuel substitution.

Increasing Efficiency of the University of Calgary's Cogeneration Plant by Capturing Surplus Heat
Gary Boguslavsky Sayun

This study explores the feasibility of installing a new electricity generation technology that utilizes the surplus heat that exists today at the University of Calgary's cogeneration power plant during the warmer months periods. Using historical data from the cogeneration power plant, heating needs from campus buildings and 30-year average weather data, the available resource is calculated allowing to choose a technology that is capable of generating electricity taking advantage of that heat energy. Organic Rankine Cycle electricity generation was chosen for its versatility and ability to generate electricity from low to medium heat sources. Considering the resource available, the costs of purchase and installation and the capacity four IT 250 ORC generator have, a payback period of 14 years expected as well as a Scope 2 emissions reduction of 1,230 tonnes of CO2 per year allowing the University to move forward with its climate action plan that seeks to propel the University as a leading educational institution in sustainability, innovation, and climate action with the final goal of being net-zero by 2050.

Learning from Hurricane Maria
Manuel Schirmer

The Caribbean region, due to its geographical location, is regularly prone to natural disasters such as hurricanes. In Puerto Rico, Hurricane Maria caused widespread destruction in 2017 while highlighting interesting patterns and difficulties in its disaster governance, including the extent to which Puerto Rico's emergency budget and decision timelines –as an associated United States territory- depended on the remote US mainland. This study presents an academic literature and policy document review of the roles of Nongovernmental Organizations (NGOs) surrounding the time of Hurricane Maria as complementary emergency assistance involved in disaster prevention, preparedness, emergency support and long-term recovery. More broadly, the study also identifies current challenges and opportunities for Puerto Rico's energy systems and emergency preparedness in light of growing hurricane projections toward the future.

Mapping Techno-Economic Feasibility of Geothermal Energy Resources in Alberta
Gordon Brasnett

Identifying favourable locations to place geothermal projects typically starts with evaluating the geothermal gradient in a region; however, the feasibility of a project also depends on ease and costs of drilling, proximity to customers, and numerous practical factors. This research meshes a variable-price model with multiple geospatial data sets using a geographic information systems (GIS) platform to produce a map set illustrating the status of Alberta's geothermal energy prospects for both electrical generation and direct use applications. By combining several map layers, a region's suitability for geothermal projects is categorized by evaluating multiple criteria. Costs and potential revenues associated with development were estimated to provide an overview of geothermal energy's economic viability across Alberta via a net present value (NPV) calculation. The resulting interactive maps provide a picture of the estimated feasibility of geothermal energy in Alberta under varying techno-economic scenarios for 40°C, 80°C, 120°C, and 150°C resource temperatures.

A Multi-Dimensional Analysis of Seasonal Hydropower Generation and Pumped Energy Storage in an Alberta Irrigation Network

Kristina Marian Evelyn Pearson

I compared three new seasonal hydropower generation (summer) and pumped energy storage (winter) projects within existing Alberta irrigation infrastructure to evaluate their environmental and economic value. I used the historical irrigation flow rates, power pool pricing, and ancillary market data to determine the range and variability of the potential energy production, greenhouse gas (GHG) mitigations, and determine the expected economic rate of returns. The energy storage was analyzed under three separate operating modes: energy arbitrage, regulating reserve, and spinning reserve market. All projects had a positive economic return, however, the only positive energy storage returns occurred when the energy storage was operating on the spinning reserve market. Furthermore, the energy storage operation was found to be a net emitter of GHGs, although the irrigation seasonal hydropower generation more than offset these emissions, and each project resulted in a net reduction in GHG emissions.

Review of Carbon Capture, Utilization & Sequestration Options for Natural Gas-Fired Power Generation

Abayomi John Oyedola

The world's glaring CO2 problem as one of the greenhouse gases causing global warming stares us in the face. Carbon Capture, Utilization, and Sequestration is one of the options to curtail this existential challenge. This research is a techno-economic assessment of a hypothetical CO2 pipeline from an NGCC power plant to a sequestration hub of the ACTL. This project answers what the role of CCUS is and how NGCC plants can continue to be relevant. The study showcases five optimized CO2 pipeline transportation routes with five CO2 pipeline sizing design parameters models, leading to seven economic CO2 pipeline construction costing models. The results identified an optimal route with an equivalent construction cost of C$324 million and depicted the project viability against a 2021 carbon tax of $40/tonne of CO2. Existing pipeline corridors and right-of-way surveys can improve pipeline optimization having direct implications on safety and project costs.

Solar PV Options to Reduce Emissions from Drilling, Completions, and Production Operations

Anisha Nikhitha Gajudhur

This research assesses options for the oil and gas sector in Canada to reduce scope 1 and 2 GHG emissions from their drilling and completions operations. This sector accounts for 26% of national GHG emissions in Canada. Drilling and completions operations contribute to a significant portion of greenhouse gas emissions which can be reduced by various options. This paper explores the techno-economic feasibility of implementing different solar photovoltaic options to offset the carbon emissions for a specific organization. Using organizational and historical data coupled with SAM simulation software, the research finds that bi-facial panel systems with single-axis tracking offer the most cost-effective solution with the lowest Levelized Costs Of Electricity (LCOEs) when compared to their mono-facial, fixed mounted counterparts. Carbon offset credits produced by the system can be used to meet the organization's emissions compliance obligations.

Technical Analysis of Water Management Approach in the Oil Industry for Concentrated Brine Resulting from Low-Temperature Distillation Technology

Sebastian Castiblanco Palomino

The development of hydraulic fracturing (HF) in unconventional reservoirs has caused water production to increase over the years, forcing companies operating in the Montney Formation to inject more produced water (PW) into disposal wells. A novel distillation technology seeks to change the status quo of PW management by producing distilled water and concentrated brine from PW. This project explores the environmental impacts and technical feasibility of injecting the concentrated brine in the Leduc Formation by fluid-fluid chemical simulations using OLI Flowsheet ESP software. The results indicate that the technology generates environmental benefits such as GHG emissions reduction, freshwater consumption, and injection of less volume of PW. However, it was evidenced that the concentrated brine generates precipitation of solids in the form of scale. Further investigation using reservoir numerical simulation is recommended to compare the magnitude of the impact generated on the formation when injecting the concentrated brine.

Wildfire Resilience in Southern Alberta

Emily Hunter

Through a qualitative case study of Southern Alberta, this research explores how Alberta communities could benefit from the development of a wildfire resilience network. Resilience networks aim to connect communities with similar vulnerabilities to build knowledge about effective risk mitigation. This research paper considers how such a network geared towards wildfire resilience could increase the accessibility of material benefits for communities in the form of financial or practical resources. Primary data has been collected through a document analysis and interviews with key policy actors, and analyzed through content analysis methods. The findings assess how a resilience network could support the existing fire management policy framework of Alberta, and result in more effective protection of valued areas and assets.

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