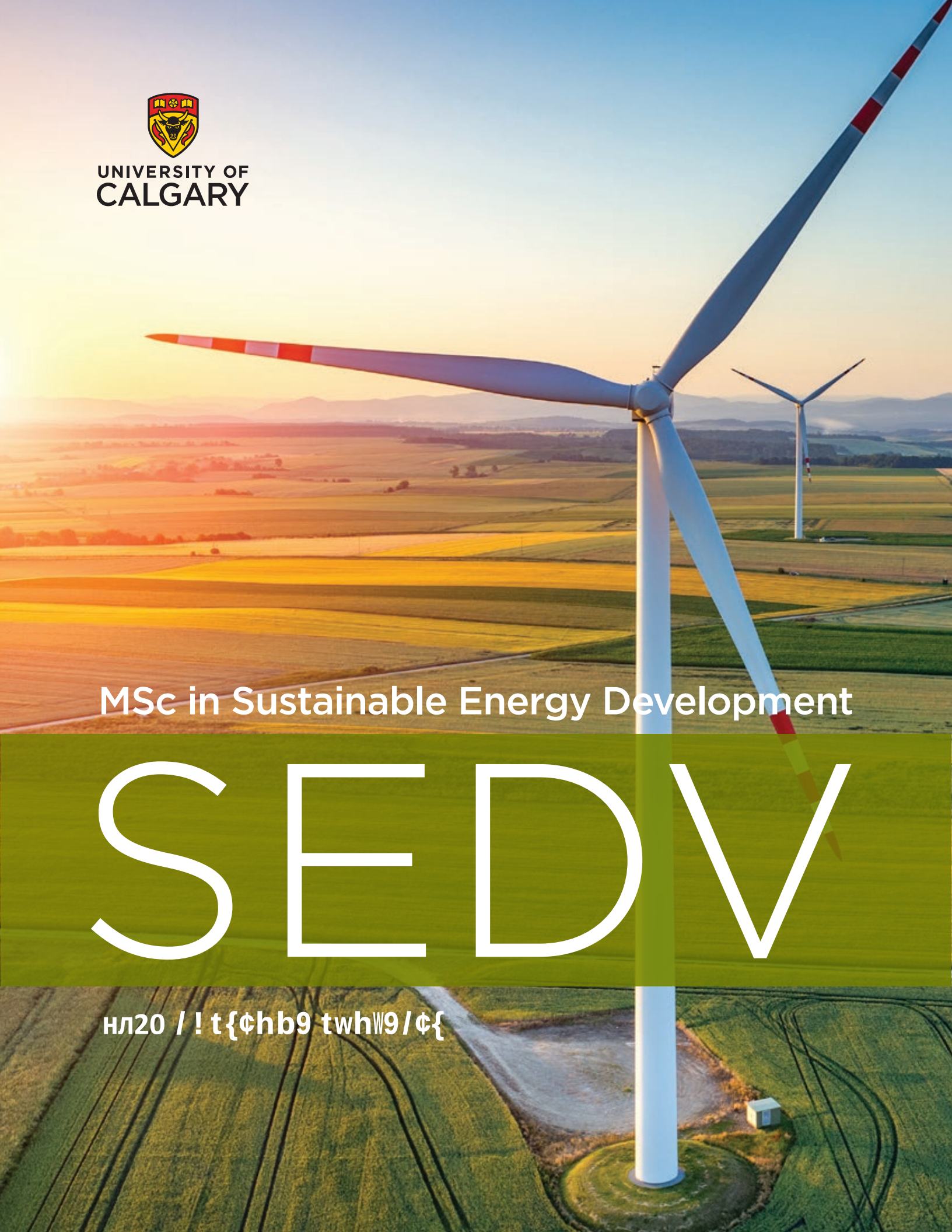

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MSc in Sustainable Energy Development

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2020 CAPSTONE PROJECTS

Alternative Solutions for Fruit and Vegetable Price Look-Up Stickers Generating Waste in the Environment

Kruti Mukeshi

Waste generation impacts the environment, energy, economy, and society. Price Look-Up stickers used on the fresh produce become environment litter, can cause compost contamination, and contribute to climate change. This research was conducted to identify alternative and sustainable solutions for Price Look-Up stickers. Two surveys were conducted for the purpose of this research. Survey I was geared towards identifying the potential for adoption of alternative solutions among produce processors and distributors . Survey II was intended for analysing sticker waste disposal practices and attitudes among end consumers. Representatives from the sticker manufacturing industry were interviewed to gain information for analysing the prospects for innovation, availability, and adoption of alternative solutions. I consulted with officials at the Canadian Produce Marketing Association to understand their position on need for alternatives. Findings from the surveys and industry consultations were used to develop recommendations for The City of Calgary.

An Analysis on the Effects of Carbon Pricing in Alberta

Yuwen Duan & Tom Di Wu

For this research, the focus will be on the carbon pricing in Alberta. As one of the leading jurisdictions in Canada for reducing GHG emissions, Alberta has the responsibility to implement policies to reduce GHG emissions, while maintaining its economic prosperity. The effects of carbon pricing policies on unemployment rate, economy diversification and socio-economic sectors will be investigated in the paper. Recommendations will be provided on how Alberta should move forward with carbon pricing after analysing the trend and relationships between carbon pricing and the economic and social structures in the province. As such, by extrapolating the results and reaching a thorough understanding of the impacts of carbon pricing, the effectiveness of carbon-pricing related policies may be bettered. Studies on other jurisdictions in Canada may be conducted in the future for comparative purposes.

Benefit-Cost Analysis of Integrating Distributed Generation in Alberta

Ankit Kirit Patel

The volume of greenhouse gas (GHG) emissions from the electricity sector in Alberta is a concern. Strong measures have been implemented by the Alberta government and the promotion of distributed generation (DG) is one of them. Despite numerous benefits, higher penetration of distributed generation will also bring challenges in the system. This research explores the societal impact in terms of economic and environmental perspectives to determine the potential of distributed generation in Alberta. In this research, benefit-cost analysis is done by quantifying all costs and benefits attributed to a distributed generator customer (or investor) in private benefit-cost analysis and perceived impacts of distributed generation on the utilities and nondistributed generation customers with public benefit-cost analysis. The result showed that the distributed generation provides net economic benefits and can reduce GHG emissions from electricity generation mix in Alberta.

Brownfields to Brightfields: Re-Purposing Alberta's Unreclaimed Oil and Gas Sites for Solar Photovoltaics

Alyssa Julie Bruce

A portion of Alberta's unreclaimed 'brownfield' oil and gas sites could be re-purposed as 'brightfields' with solar photovoltaic installations supporting provincial objectives to reduce carbon emissions from electricity generation, address brownfield liabilities and mitigate cumulative effects of development. Elemental Energy (Alberta 2003) Inc. has initiated a repurposing pilot project however formal institutions, such as policies and regulations, and informal institutions, such as norms and values, may influence expansion of this sustainable endeavour. Through interviews and document analysis, this research investigated, "What are the opportunities and barriers to developing solar photovoltaic infrastructure on Alberta's unreclaimed oil and gas sites?" The findings suggest that existing institutions support re-purposing a subset of brownfields with micro-generation systems, however policy and regulatory ambiguity hinder broader expansion by affecting the economic feasibility of distributed generation projects, limiting the number of re-purposing candidate sites and reinforcing constraining mindsets in the power generation and oil and gas industries.

Business Case for Geothermal Energy Development to Power LNG Project in British Columbia

Yaqub Olabanji Adepoju

Geological uncertainties of the Mount Meager volcanic complex in British Columbia, Canada, are analyzed to evaluate the economic viability of a geothermal power plant. This study utilizes empirical petrophysical formulas combined with field data to estimate geologic properties, including rock porosity and permeability. Flow rate, outlet pressure and temperature for three different conceptual flow models, two types of closed loop systems and one open loop system, were simulated. An economic analysis was carried out to understand the impact of rock permeability uncertainty and geothermal aquifer temperature on technical feasibility and economics viability of a geothermal power plant the complex. This study found that Enhanced Geothermal System (EGS) implementation can deliver a mass flow rate of up to 63kg/sec of 197oC fluid from the subsurface in the study area. Sensitivity analyses suggests that permeability is critical for the project economics. De-risking rock permeability with further research and reducing well costs will improve the economic viability of geothermal resource development in British Columbia and should be pursued further.

The Case for Energy Storage in Alberta, Canada

Sydney Claire Flowerday

Around the world, power grids are evolving. They represent a point of convergence for a wide range of policy objectives from economic growth to climate change mitigation. This is the case in the province of Alberta, home of a deregulated electricity market that connects Western Canada to the wider North American Bulk Electric System. Technological advancements and environmental mandates have altered how electricity is produced, distributed, and consumed. Energy storage can help the Alberta Electric System Operator navigate this transition by providing valuable grid services that ensure system reliability and optimize renewable generation. Pumped hydroelectric, lithium ion batteries, compressed air, thermal energy storage, flywheels, and hydrogen fuel cells will be evaluated for feasibility in Alberta. It was found that the deployment of lithium ion batteries and flywheels would best support the energy and regulatory requirements of the Alberta Interconnected Electric System.

Case Study to Support the Milpa Maya Through Traditional Maya Knowledge, Solar Energy, and Environment Conservation to Guarantee Food Security in Chunhuhub, Quintana Roo, Mexico

Josue Azael Hoil Basto

Indigenous Mayan communities in the Yucatan Peninsula are plagued by marginalization, poverty, and malnutrition. Furthermore, global warming is decreasing the amount of rainfall and changing seasonal periods of rain in the area. Consequently, this affects the productivity of their crops and creates serious food security problems. The Mayan milpa is a traditional system of methodical and cyclical polyculture that is closely linked to the Mayan jungle. This research aims to support food security by implementing alternative energy systems with solar sources to produce water and irrigate crops. The project integrates the three dimensions of sustainability: traditional Mayan knowledge about the practice of the milpa and the sustainable management of natural resources; the generation of solar energy as a source of electricity to remote locations; and environmental conservation through the sustainable use of water, soil, and the forest. This research was conducted using qualitative and quantitative methods. It involved a literature review in conjunction with questionnaires to the Mayan farmers.

Changing Children's Awareness and Behavior Toward Environmentally Sustainable Practices Through Educative Programs

Karla Gabriela Ordaz

Education plays a valuable role in sustainable development if linked to behavior change. This research has evaluated environmental education effectiveness to change children's, teachers', and Sustainable Energy Development (SEDV) residents' awareness and behavior toward the impact that energy has on the environment. Implementing the Theory of Planned Behavior developed by Ajzen in 1990, questionnaires were designed with queries about attitude and perceived behavioral control as variables that most influence the intention to perform a behavior. Although learning may not produce rapid behavior change, it can be useful to motivate people to adopt the desired attitude and awareness. The findings demonstrated that elementary school students are capable to learn about energy and environment, and that the educative program impacted participants' attitudes and awareness favorably. Overall students and SEDV residents gained more knowledge about environmentally sustainable practices by engaging in environmental activities. Consequently, they acquired a stronger intention to portray pro-environmental behavior.

Commercialization of In-Situ Hydrogen Production

Christopher Wulf

Mitigation of global warming requires transition to fuel sources which emit no greenhouse gas (GHG) emissions when used and produce no significant GHG emissions in their production. Proton's in-situ hydrogen production technology utilizes an approach which traps all other produced gases underground with the potential to produce such clean hydrogen. This study reviews the proposed technology components, potential synergies for renewable power storage (as hydrogen), large scale economics and life cycle greenhouse gas intensity benefits. The results show feasibility of large scale application, a positive synergy with large scale renewable energy storage (in salt caverns), a potential to produce hydrogen at scale with a cost of approximately $0.17/kg, and potential for reducing the current greenhouse gas intensity of natural gas powered gas turbine combined cycle (GTCC) electricity generation from 499.1 g CO2eq/kWh to approximately 5 g CO2eq/kWh (98% reduction) by conversion of GTCC plants to run on clean hydrogen.

Considerations for Utilizing Vertical Agriculture

Brittany Taylor

With an increasing population and impacts due to climate change, food systems have become more complex and demanding. In Canada, growing seasons are short which places a heavy reliance on importing food. This comes with health and environmental impacts, which includes a significant use of energy. Due to these issues, vertical farming has become more popular in urban areas. This study aims to look at the considerations of popular controlled environment agriculture (CEA) methods used in vertical agriculture. With this research, a foundation can be applied for decision-making surrounding urban development and food systems. By using global case studies, literature reviews and data from Harvest Hub, a basis is provided for future research where technical aspects can be assessed to make CEA more viable. It was found that most CEA methods used in vertical agriculture are energy intensive and require high initial investments, which is not sustainable for many communities.

Contribution of the University of Calgary Institutional Sustainability Strategy to the Sustainable Development Goals

Andres Gomez Blanco

This project addresses the following question: to what extent does the University of Calgary Institutional Sustainability Strategy (ISS) contribute the Sustainable Development Goals (SDGs). Recent studies do not report the contribution of the higher education sector to the SDGs. Also, the use of frameworks and guidelines is not clearly stated. This research gap is addressed by applying the SDG Compass steps to the ISS and reviewing the U of C's materiality matrix. The findings demonstrate that the Compass serves as a tool to identify the ISS contribution. Besides, the materiality matrix is a key driver in determining the material aspects in the ISS scope. Six SDGs, eight targets, and nine indicators comprise the strategy's contribution with specific actions regarding education, clean energy, innovation, responsible consumption, and climate change. Finally, 25 indicators were designed to measure the ISS contribution from 2020 to 2021.

Economic and Environmental Analysis of Carbon Fibres from Bitumen

Tarun Avtar Arya

The best way to get the maximum value out of Alberta's bitumen is by converting the low-value feedstock into a high-value product. The Bitumen Beyond Combustion program of Alberta Innovates aims to explore this pathway for three products viz Asphalt, Vanadium and Carbon Fibres. Alberta is a major producer of bitumen which can be an inexpensive feedstock for carbon fibre production, which utilizes the carbon dioxide rather than releasing it in the atmosphere. A carbon fibre plant is proposed, that over 25 years, would produce 1.2 megatons of carbon fibres from bitumen and would release 34.9 megatons of carbon dioxide. These emissions are slightly higher than 34.6 megatons of carbon dioxide produced by the current method of production for the same amount of carbon fibres. This project would require an investment of $1.2 billion, the net present value of the plant incorporating this process would be $14.5 billion.

Electric Vehicle Incentives: Reconciling Private and social Costs and Benefits

Kiana Goddard

Canada is looking to reduce its emissions by targeting the transportation sector. While there are a number of policies to reflect this, one in particular seeks to impact individual's private decision to transition their passenger vehicles from internal combustion engine vehicles to the more environmentally beneficial battery electric vehicles. Results indicate that the current federal grant incentive program for electric vehicles plays a significant effect in the costs of investing in passenger BEVs and ICEVs. These costs are evaluated through net present value equations that reflect private costs, as well as incorporate the social cost of carbon. Furthermore, an inventory of the current policies in comparison to other countries provide further indication of where Canada needs to pivot in terms of policy to reach their current targets.

An Evaluation of Cumulative Effects Assessment in the Northwest Territories

Nelson Henry Debogorski

This study investigates cumulative effects assessment (CEA) in the context sustainable development and the resulting impact on barren-ground caribou (Rangifer tarandus groenlandicus) in the Northwest Territories (NWT). This research attempts to gain insight into the role of CEA in the sustainability of this species and answer the question; has CEA been applied in NWT to adequately mitigate the impact of development on barren-ground caribou? CEA completed for five projects situated in the NWT are analysed and ranked based on an evaluation matrix developed for the study. The research findings determined that CEA in the NWT may not contribute substantive value to promote sustainability of the caribou. The CEAs evaluated did not demonstrate best practices as reported in the CEA literature, additionally the cumulative effects of development in all projects evaluated was reported as negligible. CEA practice requires re-examination and methodological development to achieve its goal to promote sustainable development.

Examine the Feasibility of Electrifying a Natural Gas Pipeline System: A Case Study on Enbridge's Westcoast Pipeline

Shengnan Li

Climate change is an evolving global issue that needs all industries to act. This research aims to examine the feasibility of reducing operational-related (Greenhouse Gas) GHG emissions at natural gas transmission pipeline through electrification, using Westcoast pipeline in BC as the case study. The research evaluated the GHG reduction potential at the pipeline's gas compressor stations under three electrification scenarios. A cost-benefit analysis was performed for each scenario and compared with baseline scenarios. All the data in the research were selected using publicly available data. The analysis suggests that electrification will significantly reduce GHG emissions at the Westcoast pipeline; however, all three scenarios would surpass baseline operational cost due to incremental electricity demand. Future uncertainties, such as changing carbon tax price, natural gas price, electricity price, and gas compressor maintenance cost, might shift the electrification project financial analysis results.

Expecting the Unexpected: Disaster Vulnerability and Emergency Planning

Claire Hosford

As climate change is projected to increase the frequency and severity of extreme weather events, communities face challenges to adapt and prepare. To address the increasing risk of natural disasters, governments have developed climate adaptation and emergency management reports and post-incident recommendations. However, implementing local measures can be daunting due to limited human and financial resources. The research question that this project investigates is: what is the compatibility of disaster risk reduction guidelines and community-identified priorities in a Southern Alberta community? As Indigenous communities in Canada continue to be disproportionately impacted by natural disaster events and account for almost 1/3 of wildfire evacuations, this report examines how community-focused risk reduction programming can help reduce disaster impacts. Through a review of historical disaster events, recent Canadian initiatives and a qualitative case study completed with Siksika Nation's Emergency Management team, this report highlights community-specific factors that can inform community emergency management planning.

Feasibility Analysis on Geothermal Heat Storage Capacity and Recovery of Alberta's Decommissioned Wells

Sarvenaz Moazami

The province of Alberta is home to one of the World's largest strategic sedimentary basins. The Oil and Gas industry has been Alberta's major source of economic prosperity for more than half a century. There are plenty of related environmental concerns with the oil and gas operations. The Earth's thermal energy potential known as Geothermal is one the most reliable sustainable energy sources with the least negative environmental impacts. In this capstone project, a feasibility analysis with numerical model was performed for heat storage and recovery, to create synthetic geothermal reservoirs in Alberta's cold shallow formations. Additionally, an analytical model was created to recover sustainable heat for space heating applications from hot deep deposited formations using the decommissioned wells. The objective of this study is to provide a sustainable solution to meet some of the Alberta's growing energy mix demand for the future while lowering the GHG emissions and negative environmental impacts of the abandoned oil and gas wells.

Feasibility of CCUS to CO2-EOR in Alberta

Richard Hares

Carbon Capture Utilization and Storage (CCUS) is a critical mitigation technology in the fight to reduce global emissions and CO2 utilization through Enhanced Oil Recovery (EOR) is an influential economic driver. This study presents a method and techno-economic model that considers reservoir suitability for CO2-EOR and price conditions at which CO2 projects become feasible and applies financial levers to identify cumulative CO2 storage potential and incremental oil recovery in Alberta. The results demonstrate that CO2-EOR in Alberta has the potential to store between 131Mt and 1.3Gt of CO2 at a minimum field-delivered CO2 price of $60/tonne. There are, however, a limited number of economic pool-clusters with material CO2 storage potential. Financial levers can bridge the gap in CO2 supply price and reduce economic risks for CO2-EOR projects to promote the further deployment of CCUS to CO2-EOR in Alberta.

Feasibility Study of Smart Charging in Electric Vehicles

Sounderya Venkatesan

Electric vehicles (EVs) are a rapidly emerging technology than can provide the opportunity to reduce emissions from the transportation sector. As EVs penetrate the transport market, electricity will become the fuel of the future and present new challenges and opportunities to Canadian utilities. This study aims to investigate the role of smart charging to address the challenges caused by EV adoption. Specifically, it seeks to examine the energy implications caused by EV charging and provide potential smart charging solutions along with policy recommendations. Most of the identified challenges are related to distribution grid, charging infrastructure and peak demand issue. Results suggest that workplace charging, time-of-use rates, and shifting load behaviour can effectively minimize the energy costs and avoid peak loads. These identified smart charging solutions can ultimately save millions of dollars to the utilities and set an example for managing energy efficiently even during the times of increased power demand.

A Financial and Technical Analysis of Alternative Heavy-Duty Trucking Options in Canada

Samuel Kagan

Canada's long-distance road freight transportation sector will require massive decarbonization efforts for greenhouse gas (GHG) emission reductions in line with Canada's targets of 30% by 2030 and 80% by 2050, relative to 2005 levels. Alternative fuel sources present a tangible pathway that is increasingly economically and operationally viable. Additionally, the Clean Fuel Standard (CFS) will likely lead to higher penetration of alternative fuels in Canada, as carbon intensity levels of fuel is enforced. The analysis in this study compares alternative technologies that may be used to transition diesel freight vehicles to low carbon or zero carbon freight vehicles. Despite the high initial costs, lithium-ion battery electric freight trucks have the lowest cost of carbon abatement among the options studies, depending on the carbon intensity of the electricity generated. The lifecycle emissions, total cost of ownership and cost of avoided emissions are compared amongst six scenarios.

Harvesting Human Energy

Guillermo Estrada

Nowadays, different technologies are being developed to harvest energy from human movement. Different companies and researchers are looking to store, produce, and increase conversion rates to generate and supply power to the utility sector reliably and cleanly. This paper evaluates the economic benefit, energy impact, and greenhouse gas (GHG) emissions reduction of harvesting human energy. The paper presents three economic analyses to determine if it is feasible to invest in green machines (i.e. bikes, treadmills), showing the pros, cons, and quantitative economic returns. Moreover, it assesses the energy supply from humans and the impact this has on the electricity sector. Results are built with information from two different institutions (Peloton Cycling and the University of Calgary Fitness Centre). In the end, even though the economic benefit is not attractive at this time, harvesting human energy holds great potential for the future when the cost of the technology decreases

Impact and Utility of the Alberta Narratives Project

Sarah Andrews

Alberta's economy heavily relies on the traditional extraction of fossil fuels, which makes discussing their role in anthropogenic climate change intensely polarizing. The Alberta Narratives Project (ANP) represents the work of Alberta environmental non-government organizations to create a narrative connection between the general public, science, and policy makers. My Capstone aims to answer how effective the language and delivery of the ANP were at creating positive discussions surrounding energy, behaviour change (on the individual level), and overall environmental impact. Interviews provided the basis for an online survey of 365 individuals. Participants found their communications capacities increased and felt confident talking about climate change and energy in Alberta. However, participants also felt unsupported by their employers and facilitators, particularly with respect to follow-up. The ANP created more confident, informed climate science communicators close to the project, but to reach the public with the ANP, ENGOs need to offer more long-term support.

Maximizing Wind Farm Power: Wake Control Using Machine Learning Algorithms

Behnam Salek

Windfarms are designed with turbines in proximity due to land and transmission line constraints. As a result, depending on the wind direction, the wake from upstream turbines will impact the downstream turbines, reducing their power generation and the overall wind farm power generation. To mitigate this effect, several wake control technologies have been shown benefit. One strategy to control the wake is to curtail the power of the most upstream turbine. In this research, machine learning algorithms are applied to model the wake effect using Power, nacelle direction, windspeed, and RPM. Next, the model is used to investigate the potential for increasing the power in the downstream turbine by derating the upstream turbine. Although there is a potential for increasing the power, the model performance was not as expected due to the insufficiency of actual data that represents the performance of the downwind turbine when the upstream turbine is curtailed.

A Methodological Roadmap to Determine the Effectiveness of Carbon Policies

Mateo Sanin Canney

In the struggle to combat climate change carbon policies have been presented as an efficient and effective method for reducing GHG emissions while minimizing economic impacts. Policy implementation worldwide has grown considerably over the past decade with an ever-growing percentage of global emissions being covered by different forms of carbon policies. There is however a low quantity of evidence-based literature on the effectiveness of the carbon pricing models currently in place. I document a statistical, econometric modeling technique developed and used by the Canadian Energy Research Institute (CERI), to evaluate the Environmental Effectiveness of different Carbon Policies worldwide. A case study using the methodology to evaluate the effectiveness of the British Columbia Carbon tax is presented showing it to be ineffective at increasing emissions effectiveness while having a positive impact on economic growth.

Microgrids as a Resiliency Measure to California Wildfires

Brendan Michael Cooke

As a result of the rapid increase in wildfire activity within the state of California, and the interaction between these fires and electrical infrastructure, the state is experiencing a lack of electrical reliability. This project offers an end-to-end review of the key factors impacting the integration of resilient residential microgrids to mitigate this loss of reliability. An in-depth review of wildfire trends, microgrid and DER technology, and their economic and environmental impacts was conducted to understand the interaction between these factors and electrical reliability. Several community scenarios were modelled using NREL's REopt Lite software to determine the specific impacts of microgrid integration in Napa County. Findings suggest that Napa presents an ideal location for microgrid investments, and projects have the potential to provide reliable revenue streams for investors depending on how operations are modelled.

An Outlook of Utility and Residential Solar Photovoltaic Growth Potential in Alberta from 2020-2030

Peter Polanowski

In this paper, I present a review of literature assessing the key factors in solar PV adoption, while also estimating installed capacity for utility-scale and residential PV installations across Alberta by 2030. Several economic and socio-demographic variables are known to contribute to solar photovoltaic (PV) distribution, such as the resource availability, installed costs, household median income, policy instruments and the availability of financial incentives. Total employment potential from resulting estimates suggest that over 17, 000 jobs (in job-years) can be created in construction and installation of solar PV installations across the province. Resulting GHG avoided emissions were also calculated from projected installed utility-scale projects. Taken together, these results will help policymakers in what policy measures can be taken to facilitate further growth in the industry, as well as provide training organizations foresight on where best to apply training programs for workers transitioning to the renewable energy economy.

The Pathway to Clean Energy: A Review of the Implementation of British Columbia Climate Change Policy and Strategies for Indigenous Communities

Susanna Chan

Climate change policies and strategies that frames the British Columbia (BC) approach to transitioning to a more sustainable future have been widely adopted in the Province of BC since the passing of the Clean Energy Act (CEA). This includes the CleanBC plan that aims to provide a pathway in achieving climate targets, including assisting Indigenous communities in the transition. This research study looks at the Indigenous components of the BC provincial policy and strategies resulting from the CEA. The first part of the project includes a BC policy and strategies literature review to gain an in-depth understanding of existing research and reports. The second and third parts include a data analysis that resulted from a survey completed with Indigenous participants to gather feedback on the CEA and Indigenous targeted initiatives. Based on results gathered, recommendations are multi-layered and encompass further collaboration in policy development, consultation, and improvement in intergovernmental relations.

A Step Towards a Lower Carbon Future: Integrating Closed Loop Geothermal Technology in District Cooling Applications

Erin Lea

This research will assess the technical, environmental, and economic feasibility of low-grade, closed loop geothermal heat extraction used for district cooling applications, specifically with the use of an Eavor-Loop™. This will be completed through literature review, interviews with subject matter experts, thermodynamic process simulations and optimization, and an economic analysis. As global warming, urbanization, and our dependency on digital storage increases, the world's cooling demands continue to rapidly grow with predictions showing that cooling demands will outweigh heating demands by 2060. Majority of current cooling systems utilize fossil fuels, emitting a great deal of greenhouse gases that have gone unchecked for decades. With the utilization of Eavor-Loop™ and absorption chiller technology, a 6,600 RT facility was designed for data center operations in California, USA with both environmental and economic benefits. This design aims to open up new, affordable possibilities with low-grade geothermal resources to meet the world's cooling demands.

Sustainable Brewing: A Study of Sustainable Brewing Practices

Effiok Inyang Jnr

The objective of this capstone project is to analyse the environmental and social sustainability practices of local breweries in Alberta. A United Nations study has projected the global population will increase from over 7 billion today to approximately 9 billion by 2050. Managing the relationship between water, food and energy is becoming increasingly critical. The recent growth within the craftbrewing industry has increased employment and economic growth in Alberta, but has also raised social and environmental concerns. This report shares insights on key performance indicators and best practices of sustainable brewing, based on a literature review, content analyses and interviews with ten local craft breweries across Alberta. It develops a benchmark among craft breweries in Alberta to determine their existing sustainable practices and what they can do as an industry to improve. Findings identified several sustainability indicators: water, energy, solid waste, carbon use, and social aspects.

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