School of Public Policy | University of Calgary

Capstone Project Abstracts

MSc in Sustainable Energy Development 2025

Discovering Innovative Solutions for a Sustainable Energy Future

This collection of abstracts showcases the exceptional work of our Master of Science in Sustainable Energy Development students, who are deeply committed to driving the energy transition. Throughout this intensive 16-month program, our students have delved into every facet of the energy industry, pushing the boundaries of what is possible. Many of our students have collaborated with industry partners, enriching their projects with real-world insights and applications. Their work reflects a diverse range of topics, from the potential of hydrogen technology and solar energy innovations to the assessment of sustainable practices across various sectors.

The following pages highlight the depth and breadth of their research, offering insights into the challenges and opportunities within the energy sector. These projects are a testament to our students' dedication to advancing sustainable energy solutions and their determination to make a meaningful impact on our world.

Advancing Climate Action Through Scope 3 Emissions Evaluation and Reporting for the University of Calgary

Masumi Dhavalkumar Vaghasiya

This study establishes a Scope 3 greenhouse gas (GHG) emissions baseline for the University of Calgary in 2023–2024 to support the institution in beginning comprehensive reporting. Using the GHG Protocol as a guide, the assessment focused on material categories including purchased goods and services, capital goods, business travel, commuting, fuel- and energy-related activities, and waste, with comparisons to the 2011–2012 baseline. A hybrid approach using procurement records, Environmentally Extended Input-Output factors, manufacturer life cycle data, travel surveys, and waste audits was applied. Results indicate that procurement and commuting are the largest contributors, while waste and upstream energy activities are smaller but still material. The analysis faced significant data limitations across nearly all categories, highlighting the need for improved data systems. Findings provide both a baseline and a roadmap to help the University of Calgary advance Scope 3 reporting and climate action.

Advancing Responsible Consumption: A Sustainable Purchasing and Reporting Strategy for the University of Calgary

Nicholas Millichamp

This capstone study investigates what strategies the University of Calgary can adopt to advance its sustainable purchasing and reporting. While the school has outlined sustainability goals in its Institutional Sustainability Strategy (ISS), there are gaps in procurement processes, data collection, and reporting systems that limit the university's ability to measure progress and align with its goals. Existing frameworks such as the UN Sustainable Development Goals (SDGs) and the AASHE STARS™ inform the research, along with a review of internal university documents. A thematic analysis of semi-structured interviews identifies barriers and opportunities according to current University of Calgary employees and highlights key themes such as the lack of clear policy or guidelines, gaps in training and capacity, and structural disconnect between departments. The research demonstrates that while there may be openness to advancing sustainable procurement, meaningful progress requires clear criteria, top-down leadership, and improved data collection.

Advancing Solar Energy in Alberta: An Assessment of Municipal Solar-Friendly Policies and Implications for Leadership in Renewable Energy Adoption

Yiming Hu

This report assesses how Alberta municipalities are implementing solar-friendly policies and initiatives in response to the growing demand for solar energy adoption and identifies which municipalities are leading in solar energy initiatives. Stakeholder interviews, document analysis, and a structured scorecard evaluation are among the qualitative and quantitative techniques used in this study to evaluate eleven municipalities based on seven major criteria: low-interest loans, financial incentives, solar-ready bylaws, priority permitting, ambition and accountability, permitting efficiency, and public education. The results show cities such as Edmonton, Banff, Grande Prairie, and Calgary demonstrating leadership through strong administrative systems and well-defined energy strategies. Smaller municipalities often lack the financial and human resources necessary to implement effective solar programs. Notable anomalies include smaller towns (Banff, Canmore) punching above their weight and larger cities (Lethbridge, Red Deer) falling surprisingly far behind. The research identified best practices, highlighted policy gaps, and recommended strategies to support all Alberta municipalities in advancing a more sustainable future.

An Analysis for Revegetation Plant Species Selection to Optimize Carbon Sequestration for the Casino Mine Project

Juste Zukauskaite

As the world moves towards sustainability, the need for raw materials is expected to increase exponentially. Mining is the most common method used to extract minerals and metals from the earth's surface. The Casino Mine Project is a proposed mine located in the Yukon Territory, and it is determined to bring economic prosperity to the Yukon while also being environmentally cautious. This literature-based capstone project examined which revegetation trial will sequester the most carbon dioxide at the tailings management facility. The results show that native plants found on the site will sequester around 115 kt of CO_2, while imported plants not found on-site but present in the Yukon will sequester around 504 kt of CO_2. Although the numbers are accurate, the calculations assume all plants will reach their full growth potential and no reversal of sequestration occurs. Future research should include planting trials to verify the calculations.

Assessing the Impact of Variations in Energy Rates and Carbon Price Projections on Low-Carbon Building System Designs in Canada

Vinuki Punara Kodithuwakku Arachchi

Achieving Canada's 2050 net-zero targets requires strategic choices in low-carbon building systems, with projections of natural gas and electricity rates, along with carbon pricing, playing a critical role in their financial feasibility analysis. Currently, many organizations still rely on fixed escalations of energy rates, risking inaccurate feasibility assessments. This research examines how six institutional projection scenarios of end-use energy rates and carbon prices affect GHG emissions and costs of residential building system retrofits in Alberta, British Columbia, and Ontario from 2025 to 2050. Results show substantial cost and emissions variations: Alberta's low natural gas prices create the largest short-term cost gap for retrofits, while British Columbia and Ontario achieve net-zero emissions by 2050 from retrofits even under modest scenarios. The findings also highlight how the natural gas and electricity cost gap decreases over time, and how utilizing scenario-based projections is important to support cost-effective, low-carbon building system decisions.

Assessing the Options for Sustainable Energy Solutions for the Okanese First Nation as a Means of Economic Empowerment

Uchenna Udobata

This research explores options for integrating renewable energy solutions within the Okanese First Nation. Inspired by the experience and success of renewable energy initiatives implemented by other First Nations, which showcased the potential for significant community benefits, this study evaluates the potential for renewable energy systems such as solar, wind, and biomass to serve as a pathway for generating sustainable energy, fostering economic growth, and delivering environmental benefits.

The methodology involved reviewing secondary data, analyzing case studies of similar projects, and applying multi-criteria decision analysis (MCDA) to evaluate each renewable energy technology based on technical, economic, and social factors.

A hybrid 5 MW wind turbine and 5 MW solar photovoltaic system was recommended as an optimal energy solution capable of powering over 2,400 homes annually, generating jobs, and preventing approximately 24,000 tonnes of CO_2e emissions each year. The study advocates for Indigenous ownership models, capacity-building opportunities, environmental stewardship, and access to federal funding programs to support implementation.

Cultural and Socioeconomic Impacts of Solar-Powered Refrigerators in the Peruvian Amazon

Charity Kangume

This research seeks to address the question: "How could solar-powered refrigerators affect the dynamics of culture and socioeconomic development in the Peruvian Amazon's Calleria District?" This study is essential because, while existing literature tends to concentrate on the technical facets of solar refrigeration in various regions, it often overlooks the distinctive human context of the Amazon. By leveraging the Impact Management Project (IMP) framework, this research not only gathers critical data but also explores the transformative potential of this technology. It promises to drive significant economic growth for local businesses, improve household food security, and empower women, who are primarily responsible for managing food. However, a significant concern for adoption is the affordability gap, as the full cost of the refrigerators considerably exceeds the community's willingness to pay. Despite this, the projected high Social Return on Investment (SROI) indicates that this intervention has substantial social and economic value. The study concludes that widespread adoption requires implementing a demonstrated pilot project, establishing local technical support, and enhancing community awareness and trust.

Decarbonizing Alberta's Oil Sands: Integrating Electrothermal Energy Storage and Renewable Energy to Reduce Greenhouse Gas Emissions from Steam Production

Victor Asiamah

Electrothermal energy storage (ETES) presents a promising pathway for decarbonizing steam production in Alberta's oil sands. This study assesses the technical feasibility, emissions reduction potential, economic viability, and regulatory environment of ETES under five electricity supply scenarios, ranging from the current Alberta grid to 100% renewable energy. Scenario modelling shows that ETES is compatible with in-situ oil sands extraction and can reduce greenhouse gas emissions of steam-assisted gravity drainage operations by up to 91.8% when powered by 100% renewable electricity. Despite higher capital costs, ETES becomes cost-competitive when carbon credits under Alberta's Technology Innovation and Emissions Reduction regulation and Canada's Clean Fuel Regulations are stacked and applied. Renewable resource assessment shows sufficient wind and solar potential in key oil sands regions, supporting private-wire ETES configurations. However, policy gaps, particularly the lack of ETES-specific protocols and capped carbon pricing, constrain deployment. The findings support ETES as a technically and strategically viable industrial steam decarbonization solution, contingent on regulatory reforms and strategic integration.

Developing and Piloting a Sustainability Materiality Assessment for the Calgary Stampede

Braedon McNicol

This research develops and pilots a sustainability materiality assessment framework tailored to the Calgary Stampede. Informed by the Global Reporting Initiative (GRI) Universal Standards and stakeholder theory, the study addresses the importance of aligning organizational priorities with stakeholder values to reduce risk, strengthen transparency, and enhance long-term sustainability performance. A survey was designed in collaboration with the Stampede's sustainability team and piloted with the Environmental Action Team, capturing stakeholder perspectives on environmental, social, and organizational topics.

Analysis of the 18 responses revealed health and safety of employees, guests, and nearby communities as the most material issue, while voluntary reporting ranked lowest. The framework demonstrates materiality assessments can provide actionable insights for strategic planning, sustainability reporting, and risk management. This work highlights the value of stakeholder engagement in guiding decision-making and establishes a repeatable process for future internal and external assessments, supporting the Stampede's sustainability leadership.

Developing a Statistical Risk Assessment and Grid Prediction Tool for Power System Reliability

Chetan Saha

Modern electricity grids face mounting reliability pressures as renewable generation expands, demand patterns shift, and extreme weather intensifies. This project developed a Grid Risk Assessment Tool to identify early warning signs of instability using historical datasets from ISOs and RTOs (AESO, ERCOT, and CAISO). A structured MySQL database consolidated system frequency, pricing, generation mix, intertie flows, and operator-declared events, from which predictive features such as ramp rates, reserve adequacy, renewable penetration, and frequency deviations were engineered. Logistic Regression, Random Forest, and XGBoost models were tested and evaluated using ROC-AUC, precision, and recall. Random Forest achieved both the strongest contextual performance and the best real-time performance. Feature analysis highlighted system electricity prices, renewable share, intertie support, and ramping activity as key drivers of instability. The findings demonstrate that predictive modeling can provide actionable early warning signals, supporting operators and policymakers in strengthening grid resilience and planning.

Enabling Sustainable Refrigeration in the Peruvian Amazon: An Integrated Energy, Environmental, and Economic Assessment

Olaseni Osho

Remote communities in the Peruvian Amazon struggle to store food and medicines safely because they lack reliable cold chains. This capstone examines whether sustainable refrigeration can improve health outcomes and livelihoods in this context. Three refrigeration pathways were compared: solar-powered compression systems (Amped EasyFreeze), propane absorption, and grid-tied compressors, across three use cases: vaccine storage, fish freezing, and flash-freezing. A cradle-to-use life cycle analysis assessed energy consumption, greenhouse gas emissions, and net present costs in Ucayali, with collaboration from Star Energy and IDESC. Results show that solar compression units deliver reliable off-grid cooling for clinics and small-scale fisheries with near-zero emissions and competitive long-term costs when battery storage and financing are available. Grid compressors provide the highest efficiency and can support high-throughput flash-freezing where electricity is stable, and carbon intensity is low. Propane units serve as a backup option but face high fuel costs and emissions. Barriers remain, including high up-front solar costs, LPG supply challenges, and limited rural grid reliability. Targeted deployment models, such as pay-as-you-go and cooperative ownership, can mitigate these constraints. This research provides evidence-based recommendations for matching technologies to use cases and contributes to Sustainable Development Goals 3, 7, and 13.

The Energy Storage Investment Act

Steven Wall

Energy storage systems are one piece of Alberta's complex electricity puzzle. They are underutilized, not yet properly integrated, and essential for decarbonization. When given the opportunity, the Member of Legislative Assembly (MLA) for Calgary-Glenmore intends to introduce a Private Members' Bill (PMB) titled *The Energy Storage Investment Act.* The goal of this PMB is to create enabling legislation to enhance grid reliability, increase affordability, and attract new investment into Alberta's electricity sector. In Alberta's legislature, PMB's help focus government priorities and direct work to agencies and ministries, but they cannot include financial commitments.

A literature review, a market analysis, and cross-jurisdictional assessments focused on California and Texas will complement expert information and opinions from official transcripts of MLA-led stakeholder engagements. This research will demonstrate energy storage expansion is a viable solution under the right circumstances and will identify economic and policy opportunities to influence enabling legislation to prepare for a future policy window.

Evaluating Emerging Municipal Wastewater Treatment Technologies

Koebillah Crichlow

Municipal wastewater treatment plants (WWTPs) are among the most energy-intensive systems and contributors to greenhouse gas (GHG) emissions, making them a critical focus for Canada's net-zero transition. This study evaluates three emerging technologies: Anaerobic Membrane Bioreactors (AnMBR), Anaerobic Ammonium Oxidation (Anammox), and Thermal Hydrolysis with Anaerobic Digestion (THP + AD), in comparison to conventional systems. Using a comparative framework, energy balances, GHG emissions modeling, and policy alignment analysis were conducted to assess their potential for reducing carbon footprints, optimizing energy use, and supporting Canada's climate goals. Results show while some emerging systems have higher operational energy demands, they achieve net energy recovery and significantly lower emissions when resource recovery pathways are considered. Policy analysis highlights the importance of financial incentives, regulatory amendments, and technical capacity support to accelerate adoption. The findings provide policymakers, utilities, and industry stakeholders with practical insights on advancing low-carbon wastewater treatment solutions aligned with Canada's 2050 net-zero targets.

Exploring Biochar Production at the Bow Valley

Oluwafemi Fatoba

This project assesses the techno-economic feasibility of biochar production from 316 hectares of post-harvest forest residues in Alberta's Bow Valley fireguard multi-year initiative. With an estimated biochar yield of 1,523 tonnes over a 3-phase period via slow pyrolysis, the study models three production scenarios: mobile (fully deployable), hybrid (mobile with centralized processing capabilities), and centralized (fixed-location facility). Each was evaluated for capital and operational costs, carbon credit potential, and profitability. A single, three-, and five-year Net Present Value (NPV) analysis showed the hybrid system achieving the highest returns. While centralized systems offer long-term integration potential into municipal infrastructure networks, they face higher capital barriers. Sensitivity analysis tested revenue changes from biochar and CORCs. The study recommends piloting a hybrid model for early adoption while monitoring policy and buyer trends. Further research is needed on full lifecycle emissions, co-product utilization, and site-specific logistics.

Feasibility Assessment of Electro-Thermal Energy Storage Adoption in Alberta's Steam-Intensive Industries for Industrial Decarbonization

Oluwaseyi Taiwo

Alberta's steam-intensive industries, such as oil sands, chemical manufacturing, and pulp and paper, are critical to the province's economy but contribute significantly to greenhouse gas emissions due to their reliance on fossil fuel-based steam generation. This study investigates the feasibility of adopting Electro-Thermal Energy Storage (ETES) systems to decarbonize these industries and enhance renewable energy integration in Alberta. Through a mixed-methods approach, including literature review, quantitative data analysis, and techno-economic modeling, the research identifies key steam-intensive sectors, assesses their thermal demands, and evaluates the technical and economic viability of ETES.

Findings indicate that commercial ETES technologies, such as molten salt and concrete/rock storage, can meet the high-temperature steam requirements (180–565°C) of Alberta's industries, offering up to an 80–90% reduction in emissions when powered by renewable electricity. This encompasses a broad range of electrification technologies. However, these estimates are based on modeled best-case scenarios and vendor projections rather than real-world operational data.

Economically, ETES adoption could yield significant carbon cost savings under Alberta's Technology Innovation and Emissions Reduction (TIER) regulation, with an estimated annual abatement of 33.4 million tonnes of CO_2 for the oil sands sector alone. However, high capital costs and substantial electricity requirements highlight the need for robust renewable energy infrastructure and supportive policies. The study proposes a strategic roadmap for ETES deployment, emphasizing pilot projects, policy incentives, and grid enhancements. Despite data limitations and the emerging nature of ETES, this research underscores its potential as a transformative solution for industrial decarbonization, aligning with Alberta's sustainability goals and the United Nations Sustainable Development Goals (SDGs) for clean energy, climate action, and industry innovation.

Practical Solutions to Decarbonize Mining Operations: A Case Study of a Copper Mine in British Columbia Using Renewable Diesel

Toluwanimi Ogundipe

The mining sector is responsible for extracting essential minerals vital for the clean energy transition, and its operations must be conducted sustainably to lower GHG emissions while maintaining productivity. This study examines the feasibility of using renewable diesel to reduce carbon emissions from haul truck fleets at a copper mine in British Columbia. It highlights the role of renewable diesel in achieving regional carbon reduction targets for diesel-intensive mining. A mixed methodology combining case study and quantitative analysis of two scenarios, the base case (100% traditional diesel) and a blend (renewable and traditional diesel at varying ratios), was employed. Results show no performance loss (0.34 L/t ore versus 0.33 L/t ore) with blends, a 42% annual GHG reduction, and 59% lower emission intensity. Emission levels below benchmarks enable significant tax savings. The findings confirm renewable diesel as a cost-effective solution for decreasing haul truck emissions.

Techno-Economic Analysis and Comparison of Battery- and Hydrogen-Based Energy Storage Systems

Abdul Wahab Abdul Kather

This study evaluates three major energy storage technologies: lithium-ion battery systems, hydrogen fuel cells, and hydrogen-argon internal combustion engines, as candidates for grid-scale energy storage, with the aim to answer the following research question: Which energy storage technology offers the most environmentally sustainable and cost-effective solution for Canada's renewable energy integration goals? The study fills a gap in comparative, scalable life cycle analysis of these technologies. Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methodologies employed in this research reveal that the hydrogen-argon internal combustion engine option exhibits the lowest manufacturing-phase greenhouse gas emissions and can be cost-competitive at low or negative electricity prices; however, these emissions are sensitive to grid carbon intensity. Lithium-ion retains the lowest LCoS under standard, static market conditions, but in a dynamic regime of excess renewable energy, hydrogen-based systems gain additional economic advantages, emphasizing context-sensitive trade-offs in the Canadian energy transition.

Techno-Economic Study on Aircraft Emissions Reduction at YYC Calgary International Airport

Karen G. Garrido

A techno-economic study was conducted to identify a set of financial schemes and operational practices that the Calgary Airport Authority can implement to reduce aircraft ground emissions at the YYC Calgary International Airport in three key operational areas: (i) ground support equipment (GSE), (ii) aircraft engines, and (iii) aircraft gate operations. Analysis of the aircraft's path from taxiing to gate operations shows that energy efficiencies and emission reductions ranging from 85% to 95% could be achieved. These findings are based on models where aircraft are towed to the gate by external electric GSE, the Auxiliary Power Unit (APU) is disconnected and powered by an electric Ground Power Unit (GPU), and all-electric or mixed GSE fleet configurations are used to service the aircraft at the gate. This study proposes an incentive-penalty approach to improve performance in GSE anti-idling practices and APU substitution to reduce emissions.

Villages Where Healthy Longevity Happens: Researching Market Demand to Prioritize Health and Longevity in Community Development

Kristy Kwan

FuturVille is a health and longevity-focused company that is developing a network of health-focused regenerative villages in collaboration with local developers. FuturVille's mission addresses two of the UN Sustainable Development Goals: SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities). The organization plans to achieve this through innovation and smart technologies, extending the lifespan of materials and systems, and promoting the health of people and the environment. This study is a consumer perception study that examines the public's preferences for health and wellness and their prioritization of environmental initiatives. A survey was distributed, and the research found that most respondents aspire to live for 10+ healthy years, want to receive psychological and physiological treatments as part of a regenerative village, and would actively participate in community events. Based on these findings, recommendations are provided to FuturVille and can be used in future village planning and communication.

Waste Heat Recovery and Utilization Potential from Data Centres in Alberta

Caroline Bartlett

Data centres in Alberta are poised to double the province's electricity demand. After data processing, most of that electricity becomes waste heat. This study quantifies the technically recoverable thermal energy from 11,879 MW of proposed data centres seeking grid interconnection in Alberta and models the environmental and economic benefits of using recovered heat to displace natural gas for space heating. Using a recovery efficiency of 68%, each MW of IT load could offset approximately 1,175 tCO_2e annually, equivalent to $65,280 per year in fuel costs when displacing natural gas. This research also explores how outdoor temperature impacts cooling system electricity consumption under an immersion cooling configuration. Using a Power Usage Effectiveness model, results show negligible differences across Canada and a 3% increase when compared to Dallas, TX. The study emphasizes how district heating can unlock waste heat recovery potential and help integrate Alberta's data centres into a sustainable energy transition.

Thank You to Our Industry Partners

We extend our sincere gratitude to our industry partners for their continued support and collaboration. Your engagement provides our students with invaluable opportunities to connect classroom learning with real-world practice, while advancing innovation in the energy and environment sectors. Together, we are building stronger pathways for knowledge, growth, and impact.

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