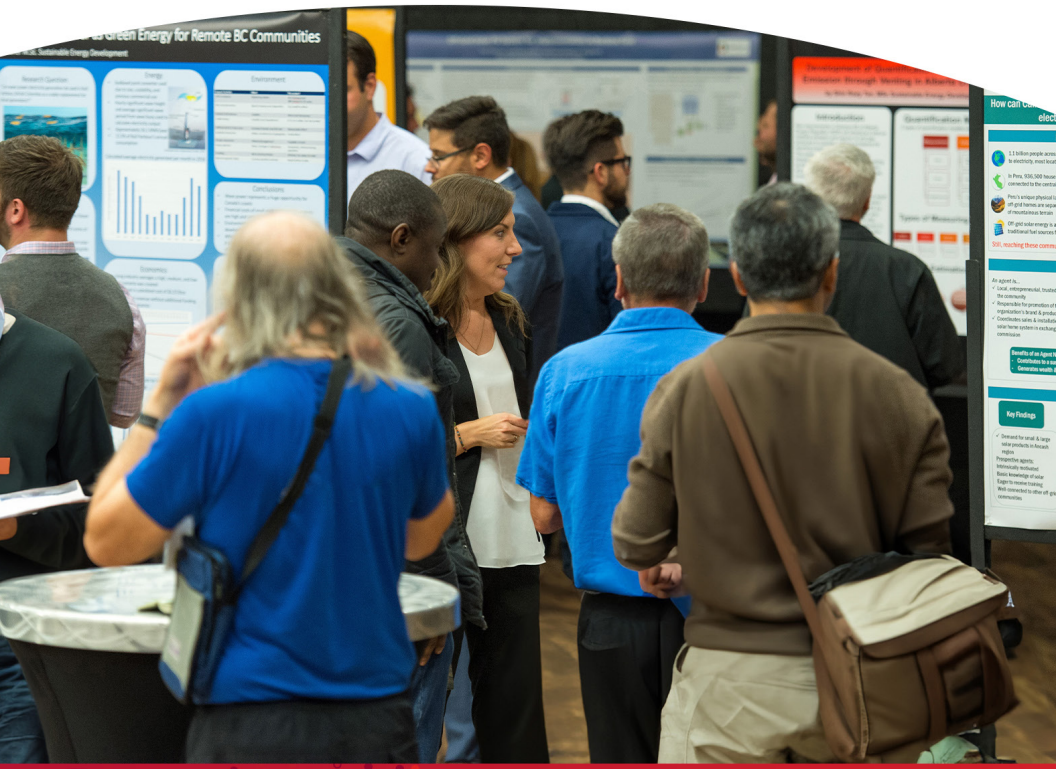
School of Public Policy | UNIVERSITY OF CALGARY

Capstone Project Abstracts

MSc in Sustainable Energy Development 2024



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 Circular Economy Principles in the Solar Industry

Olere Ijasan

This project explores the challenges and opportunities for integrating the principles of a circular economy within Canada's solar energy industry. The research assesses the environmental, social, and economic benefits of advancing these principles through literature reviews and interviews with industry professionals. It also examines the regulatory landscape and the role of technological advancements in promoting sustainable practices.

The findings highlight growing concern over solar panel waste and the need for effective waste management strategies to mitigate environmental hazards. Recommendations include developing robust recycling services with support from the Canadian Association of Recycling Industries to manage the expected end-of-life waste. Establishing a market for resused panels and advancing sustainable, recyclable solar panel technologies will be critical to achieving a circular economy.

This research aims to contribute to the existing body of knowledge by providing actionable insights for industry stakeholders, policymakers, and investors, to foster a circular solar industry.

Advancing Sustainable Construction: Exploring Bio-based Insulation Materials for Eco-Friendly Building Envelopes in Canada

Mahsa Mohajeri

Mitigating the life-cycle carbon emissions of building materials is key to reducing the environmental impacts of the construction industry,, one of Canada's highest-emitting sectors. While enhancing operational efficiency often increases the demand for fossil fuel-derived insulation, achieving net-zero buildings requires addressing both operational and embodied carbon emissions. In Canada, carbon storage insulation offers a great opportunity for more sustainable construction.

This study conducts a comparative life cycle assessment (LCA) of three insulation materials for a hypothetical Calgary office building using One Click LCA, focusing on hemp fibre insulation's greenhouse gas emissions relative to commonly used materials. The research also explores policy strategies for calculating embodied carbon to improve early design decisions, emphasizing the importance of harmonizing Product Category Rules and standardizing Environmental Product Declarations to enhance the reliability of LCA results.

An Analysis of Policy, Regulatory, and Environmental Impact Assessment Requirements to Support Sustainable Development of Nuclear Energy in Malaysia

Ahmad Zulhairi Mahadi

To achieve Malaysia's net zero greenhouse gas emissions target by 2050, the potential role of nuclear power in the country's energy mix must be reevaluated. This research investigates the policy, regulatory, and environmental impact assessment (EIA) frameworks necessary for the sustainable development of nuclear energy in Malaysia. Through a pertinent literature review and a structured analysis, the research compares nuclear energy development in Malaysia, Canada, Japan, and various developing nations.

It also underscores the need for a comprehensive and robust policy framework that addresses nuclear energy, a strengthened and independent regulatory regime, and a more transparent and participatory EIA process. Additionally, the research explores the potential for nuclear energy sustainable development tools such as global partnerships, small modular reactors, and regional cooperation. Through these practices, integration of nuclear energy into Malaysia's portfolio could become more publicly acceptable, contributing to net-zero emission and energy security objectives.

Assessing the Value of an AgriSolar Shelter in a Community Setting

Lorena Cortes

This project investigates the effectiveness of AgriSolar Shelters, implemented by STAR Energy Solutions, to address climate change impacts on crop production, enhance food security, and build community resilience in an urban setting. Motivated by global challenges including climate change, the project aligns with the growing interest in the AgriSolar initiative, which combines renewable energy generation with sustainable agriculture.

The project aims to promote sustainable development and community involvement while contributing to the advancement of the United Nations Sustainable Development Goals, particularly Zero Hunger, Good Health and Well-being, and Climate Action. This study intends to contribute to the knowledge base of AsgriSolar Shelters and offer insights into enhancing local communities' resilience to climate change.

Calgary as a Sustainable Tourism Destination

Kori Stosky

Sustainability drives competitiveness for tourism destinations. When looking to either visit a location or host conventions, meetings, or events, both local and international visitors and clients are increasing their expectations of a destination's sustainability performance. This, coupled with the increase of travellers putting pressure on the planet's natural resources, demands the sector to re-evaluate how well the environmental, social, and cultural systems of a destination are managed and protected.

This research used the Global Destination Movement's GDS-Index to measure how Calgary performs as a tourism destination. Sustainability is measured in 77 indicators within four categories (social, environmental, supplier and destination management organization performance) and is aligned with the UN's Sustainable Development Goals. Recommendations were put forward to drive performance year-over-year, focused on program development and meaningful engagement. This research supports the sustainable and regenerative motivations of Calgary's tourism industry, enabling the destination to remain competitive within a growing sector.

Climate Adaptation Practices Among Power Generation and Natural Gas Companies in Alberta

Abosede Dele-Ijagbulu

This research assesses how power generation and natural gas companies in Alberta are planning for and implementing measures to address the effects of climate change on their assets and operations (i.e. climate adaptation planning). It evaluates the availability of climate adaptation policies and the coordination approach in place to minimize the risk of electricity outages to Albertans.

Data were obtained from interviews, surveys, publicly available reports, guidelines, and academic papers, and analyzed in line with the study objectives. The results indicate although no direct climate adaptation regulatory requirements or policies exist for power generation and natural gas companies in Alberta, the companies assessed nonetheless have measures in place to address climate change related risks. The results also show that there are coordination measures in place to minimize the risks posed by climate change to the supply component of Alberta's interconnected electric system.

Consequences of Government Missteps in Renewable Energy Policies

Nilesh Prafulchandra Joisar

The world has experienced rapid changes in energy policies in recent years, significantly influencing renewable energy development. This research aims to explore how policy uncertainties affect the growth of renewable energy investments. It focuses specifically on solar and wind energy policies in Alberta. The study includes insights from expert interviews to identify global best practices that Alberta could adopt for a faster recovery from the uncertainty caused by the moratorium on renewable project approvals.

The findings confirm that policy uncertainties have a negative impact on renewable investments. The research recommends the Government of Alberta establish an expert task force to develop an integrated energy system plan. This plan should take a technology-neutral approach to meet net zero commitments.

An Evaluation System for Measuring Climate Action in the Bow Valley Region of Alberta

Assa Doukoure

The Biosphere Institute of the Bow Valley has emerged as a pivotal player in addressing climate change by raising awareness and implementing environmental protection projects in its region. By measuring its performance, the Biosphere Institute can further enhance its efficiency and effectiveness, ultimately amplifying its impact. This study explores "*What tools and methodologies are most effective for non-profit organizations to evaluate and enhance their climate action projects?*"

An analysis of widely recognized sustainability reporting frameworks was conducted to identify key elements that are both useful and adaptable for the specific needs of this organization. The findings were applied to six climate projects to determine the success and effectiveness of the Biosphere Institute's work. The results reveal the Biosphere Institute successfully increased awareness, promoted collaboration, set good foundations for future projects, and even reduced green house gas emissions. The study was not conclusive in determining the Institute's effectiveness in reaching these outcomes but the results reveal it successfully increased awareness, promoted collaboration, set good foundations for future projects, and even reduced green house gas emissions.

From Province to Planet: Exploring Alberta's Hydrogen Technology Transfer Potential

Kamran Chaudhry

This research aimed to answer the question: "*Are there opportunities for transfer of key hydrogen technologies funded by Alberta?*" Built upon the pillars of energy, environment and technology, the research examined opportunities for technology transfer of provincially funded hydrogen initiatives. A multi-layered methodology was used in the research, encompassing a thorough literature review, critical analysis of provincially funded hydrogen technologies, and a global industry analysis to gain market insights. Results of this research affirm several key clusters of Alberta-funded technologies demonstrate significant potential for technology transfer. A nuanced understanding also emerges that the most immediate and impactful opportunities for technology transfer likely exist within Canada, where collaboration with other provinces and Indigenous communities can drive significant advancements in the hydrogen economy. By continuing to foster innovation, and building strong partnerships, Alberta can play a pivotal role in the transition towards a sustainable net-zero future.

From Wells to Watts: Enhancing Upstream Oil and Gas Sustainability with Solar PV

Jeffrey Clark

The oil and gas industry is responsible for 60 per cent of Alberta's greenhouse gas (GHG) emissions, with CO2, primarily from fuel combustion, accounting for 76 per cent of the 158 million tCO2e emitted by the industry. In 2022, Alberta's conventional oil and gas industry emitted twice the GHGs per barrel than the global average due to high energy inputs during production. The province also has Canada's largest solar photovoltaic industry, supported by high solar irradiance and favourable regulations. This research explores the synergistic opportunity of solar PV microgeneration with oil and gas production to economically reduce emissions. By utilizing the oil production GHG emissions estimator tool and publicly available industry data, more than 200 wells across 276 km^2 are analyzed. The analysis demonstrates an emissions reduction of 8,062 tonnes of CO2e from 94 per cent of the wells investigated is possible with positive economic returns.

The Growing Requirements of Avoided Emissions (Scope 4) and its Accounting by Organizations in Emissions Reduction Projects

Nana Afua Baisiwaa Myers

Reducing greenhouse gas (GHG) emissions is crucial for addressing climate change. The UN's Paris Agreement aims to limit global warming to below 2°C, with a goal of 1.5°C. While emissions removal initiatives are important, the path to net-zero remains uncertain. Scaling climate solutions to avoid emissions is essential to achieve a net-zero future. Organizations that measure their GHG emissions gain a competitive edge, driving financial growth while contributing to global decarbonization. This study examines the need to address Avoided Emissions (Scope 4) and how organizations account for them in emissions reduction projects. Methodologies included reviewing sustainability standards, frameworks, regulations, and interviewing industry experts. The results highlight the challenges in understanding and implementing Scope 4 methodologies. Despite some innovative projects, inconsistencies in standards and methodologies undermine the credibility and consistency of reported emissions, limiting their usefulness for decision-making and overall GHG reduction.

The Impact of Rising Interest Rates on the Financial Viability of Renewable Energy Projects in Canada

Kento Watanabe Gomez Navas

Canada's commitment to net-zero emissions by 2050 will require substantial capital investments, estimated to reach $2 trillion. This research examines how rising interest rates could impact the speed and breadth of the broader energy transition. This is achieved by focusing on project cost, value, profitability, interest payments, and the role of government incentives.

An economic analysis of a hypothetical onshore wind project in Alberta was conducted using levelized cost of energy calculations, discounted cash flow analysis, and derivatives costing. The research identifies market-based solutions and policy recommendations to mitigate the effects of these interest rate impacts, ensuring a successful energy transition.

Life Cycle Assessment of Flame-Resistant Textiles Used in the Production of Occupational Safety Clothing: A Focus on the Personal Protective Equipment Industry

Okite Ikimi

Flame-resistant textiles are crucial for workers' safety in various industries, but their production and disposal can have environmental consequences. This study presents a comparative life cycle assessment of three commonly used flame-resistant fibers in the personal protective equipment industry: flame-resistant cotton, modacrylic, and meta-aramid. Using the life-cycle assessment methodology, which encompasses all life cycle stages — from raw material extraction and production to transportation and end-of-life — this research aims to identify the most sustainable fiber option.

This research conducts a comparative analysis of the environmental profiles of each fiber type across selected impact categories to achieve its intended results. Additionally, it includes a social life cycle assessment to evaluate the social hotspots during garment production concerning fair labor practices. The findings will contribute to informed decision-making that balances worker safety with environmental responsibility, promoting both environmental protection and social responsibility within the industry.

Multi-Residential Buildings in Alberta's Microgeneration Regulations

Obinna Maxwell Uhuegbu

This research investigates the complexities of deploying microgeneration technologies in Alberta's Multi-Unit Residential Buildings). The residential sector accounts for approximately 75 per cent of global building energy use and 28 per cent of global electricity consumption. The research objectives include analyzing the challenges in deploying solar photovoltaic technology, estimating potential clean energy capacity, assessing greenhouse gas (GHG) emissions offset, and identifying financial incentives that could benefit apartment owners in MURBs within the scope of the broader policy framework.

The qualitative and quantitative analysis show that stakeholders generally possess a positive attitude toward microgeneration technologies, and considerable potential exists for solar energy generation and GHG reductions. Leveraging sustainable design principles, Multi-Unit Residential Buildings have the potential to utilize their extensive infrastructure to actively participate in the electricity value chain and expedite Alberta's grid decarbonization efforts in alignment with its 2030 target.

Natural Gas Pyrolysis Applications in Gas Compression

Layne Holm

Canada has set agoal of being net-zero emissions by 2050. This paper explores if hydrogen production from natural gas can be used to provide an economically viable, lower greenhouse gas-emitting alternative fuel source. This study reviewed the options of pyrolysis methods in the current literature, including emissions of system configurations that apply to plasma pyrolysis; studies by Okeke et al. (2023) and Shokrollahi et al. (2024) provide the basis for the energy, cost, and emissions comparison models.

Three system configurations were used for comparison: 30MW Gas Turbine, 30MW H2 Turbine w/Plasma – Electric, and 30MW H2 Turbine w/Plasma – Natural Gas. Plasma pyrolysis was seen as a viable option due to low emissions and high-quality carbon black and hydrogen production. This paper confirmed that a lower greenhouse gas-emitting fuel source can be produced. However, it does not appear to be economically viable.

Renewable Energy Development on First Nations Lands in Western Canada

Karan Wadhwani

This paper will explore the advancements of Renewable Energy Projects on First Nations Lands in Canada and will analyze the regulations, laws, gaps, and perspectives across different jurisdictions. The purpose of this study is to identify the gaps and challenges in current regulations around reclamation and remediation responsibility on First Nations land or traditional lands. This study is particularly important as Canada moves to net zero and the demand for renewable energy increases. The research will draw from various organizations, research institutions, governments, and arms-length associations, and will examine the rules, laws, and regulations governing the country, province, cities, and First Nations communities. The research focuses on the challenges for the First Nations communities face, such as access to capital, financial assurance, laws around reclamation laws, and partnerships for renewable energy projects on sovereign lands.

Supply Chain Management of Carbon Capture Technologies in North America: Barriers and Enablers

Ejiroghene E Onoyivbe

This study evaluates the supply chain for amine-based Carbon Capture and Storage (CCS) technology to investigate its viability and identify challenges and opportunities in the North American market. The focus is on amine's role as a key raw material in CCS. The research is timely given the concern the International CCS Knowledge Centre' over supply risks and gaps in the amine market, fueled by an anticipated surge in CCS projects between 2028 and 2032, driven by emission reduction policies. Leveraging the Industry 4.0 paradigm, the study delves into five dimensions of the amine market to assess its supply chain readiness. It provides critical insights for policymakers, industry players, and academics, highlighting the intricate link between government initiatives and supply chain effectiveness. The study provides a roadmap for overcoming barriers and harnessing enablers to promote CCS technology uptake effectively.

Techno-Economic Assessment of Using Waste Heat from a Gas Plant to Heat a Greenhouse Operation in Northern British Columbia

Stuart Mills

This report investigates the technical and economic feasibility of meeting a greenhouse's supplemental heating and electricity requirements in northern British Columbia with waste heat from a natural gas compression plant. It proposes providing supplemental heating and electricity to the 3,136 m^2 greenhouse through in-floor heating and an organic Rankine cycle. (An environmental assessment of the greenhouse operations compared its performance to a greenhouse heated with combusted natural gas. A transient system simulation tool (TRNSYS)was used to model the energy demands and revealed the proposed greenhouse consumed 2,264 MJ/m^2 per year of gas for supplemental heating and had a peak electricity demand of 153 kW, consuming 1,138 MWh of total electrical energy. The greenhouse has a payback period of 4.5 years, a 20-year net present value of $1.241 million, and a 20-year Internal Rate of Return of 31 per cent. The proposed greenhouse will save 335 tonnes of CO2e compared to an natural gas greenhouse.

Techno-Economic Feasibility of Acid/Base Flow Batteries: A Long Duration Energy Storage Assessment for Behind-the-Meter Industrial and Commercial Customers in Alberta, Applying Arbitrage Opportunities and Value of Lost Load Considerations

Hunter Jackson Brett

The technological evolution of the Acid-Base Flow Battery (AB-FB) has led to a unique opportunity to utilize these batteries as a method for long-duration energy storage. Flow batteries are positioned to bridge the gap between traditional lithium-ion battery storage and storage technologies that reach from days to months, such as large-scale pumped-hydro storage. This has created a new opportunity for commercial and industrial-scale facilities to pursue the use of AB-FBs as a behind-the-metre storage option.

Alberta has recently seen increased market volatility, partially due to the growing presence of intermittent renewable electricity generators. This creates a potential environment for a battery to generate value for a customer through arbitrage opportunities and protection against potential periods of lost load. This paper assessed the techno-economic feasibility of implementing AB-FB technology, exercising energy arbitrage opportunities, and evaluating the value of lost load for behind-the-meter customers in Alberta.

Techno-Economic Feasibility Study for a Deep Geothermal System at YYC Calgary International Airport

Leanne Komaromi

A techno-economic feasibility study was conducted to assess the viability of a deep geothermal system at YYC Calgary International Airport, considering the estimated subsurface conditions and supporting the Calgary Airport Authority's net-zero targets. The National Renewable Energy Laboratory's GEOPHIRES-X software was used to simulate reservoir, wellbore, and surface plant performance to estimate energy production and cost for a closed-loop geothermal system (CLGS).

Results show that a CLGS is technically and economically feasible when configured for direct-use heat applications. Comparison with the modeled business-as-usual forecast demonstrates a positive impact on overall energy use, emissions, and energy costs throughout the study period. The CLGS for direct-use heating performs better than a solar photovolataic (PV) array with battery energy storage for the same application. However, when assessing electricity generation, the solar PV array outperforms the deep geothermal system.

Towards Sustainable District Heating Solutions for Łíídlıı Kúé First Nation, Northwest Territory

Doris Ross

This research explores sustainable district heating solutions for the Łíídlıı Kúé First Nation community in Fort Simpson, Northwest Territories. The main objective is to identify cost-effective clean energy options that align with the community's unique heating requirements and self-sufficiency goals. The methodology involves examining and analyzing various heating technologies, integrating relevant data from previous studies, and implementing a systematic approach to ensure scalability, comparability, and reliability. The research considers biomass and geothermal energy as alternatives to fossil fuel-based systems, evaluating their technical feasibility, economic viability, and environmental impact. This study seeks to develop a decision-making reference that empowers the First Nation to create an energy roadmap towards economic independence and sustainability by incorporating government policies, funding opportunities, and community engagement.

Transitioning to Hydrogen-Battery Hybrid Fishing Vessels in Digby, Nova Scotia

Talia Grunow

Nova Scotia's commitments to net-zero GHG emissions by 2050 has led to many industries searching for ways to decarbonize. In alignment with this goal, the Municipality of Digby is exploring opportunities to produce green hydrogen locally at its wharf for use by marine vessels. This initiative involves generating electricity from wind energy and producing hydrogen through water electrolysis. This research examines the energy requirements and cost to do this at the local level. Four scenarios for hydrogen production are mapped out, providing options to Digby.

The levelized cost of hydrogen across these scenarios' ranges from $5.26 to $8.01 per kilogram. While this cost could reduce the 20-year lifecycle operating cost of a hydrogen-hybrid vessel to between $456,495 and $533,830, it remains higher than the operating cost of a diesel vessel at $349,040. However, the difference is small enough to make bidirectional charging and government subsidies feasible to cover the cost differential.

The True Cost of Diesel in Remote Communities of Nunavut: A Triple Bottom Line Cost-Benefit Analysis

Henrique Ricchetti

Nunavut is Canada's largest territory, encompassing 25 remote communities that primarily rely on diesel-fueled electricity along with heat generators and boilers. Diesel-based generation has been a reliable and cost-effective energy source given the lack of dispatchable alternatives. Geographical limitations, infrastructure, and government policies have also favoured diesel reliance; however, these systems do not fully account for the socioenvironmental impacts of diesel use. This research analyses the true cost of diesel as a fuel to understand the implications of its continued use until 2050, reflecting on the effects of externalities, policies, and infrastructure, along with a comparison to the energy transition costs.

The results indicate this dependence could reach $27 billion by 2050, factoring in electricity and heating expenses. Additionally, a triple-bottom-line cost-benefit analysis was conducted to compare the capital investment required to transition to renewable energy, indicating this investment could be lower when the true cost of diesel is considered.

Using Pulsed Methane Pyrolysis to Create a Clean Hydrogen Hub in Alberta

Kurt Middleton

Hydrogen has significant potential to advance the energy transition in Canada. This research is a technoeconomic analysis of a proposed hydrogen hub in Alberta, deploying low emission Pulsed Methane Pyrolysis. This hub could meet future clean hydrogen demand from nearby gas fired electricity generating facilities and heavy-duty trucks equipped with fuel cells. The solid carbon co-product could either address existing industrial demands or be expanded to new applications.

This research relies on primary and secondary data to develop technical, cost, and market assumptions to understand the delivered cost of hydrogen from Pulsed Methane Pyrolysis at different deployment scales versus the cost of the incumbent fuel. Larger-scale production offers the lowest costs, and the economics of providing hydrogen to heavy-duty transportation currently appear to be more favorable than for electricity generation. Policies and incentives supportive of clean hydrogen from methane pyrolysis will be important to advance this technology's deployment.

Waste Heat to Electricity: Techno-Economic Feasibility of the Organic Rankine Cycle at the University of Calgary's Central Heating Plant

Areej Khaddaj

This research aims to assess the technical and economic feasibility of implementing an Organic Rankine Cycle generator to capture excess thermal energy during the summer months at the University of Calgary. The primary focus is on integrating ORC technology into the existing Combined Heat and Power Plant infrastructure to enhance year-round efficiency. By utilizing surplus heat from the cogeneration unit, the project seeks to optimize energy utilization, minimize carbon emissions, and support the University of Calgary's sustainability objectives.

This initial feasibility assessment indicates the project would produce an additional 2,800 MWh of electricity per year and reduce annual Scope 2 carbon emissions by 1,320 tonnes of CO_2e. Additionally, the financial analysis estimates a simple payback period of eight to 10 years, with a Net Present Value between $1 million and $2.7 million for a 20-year project life.

Widespread Urban Solar Energy: The Role of Aggregators in Calgary

Edison Alvarez

This research examines the potential of energy aggregators in integrating Distributed Energy Resources (DERs) into Alberta's electricity grid, with a focus on urban solar photovoltaic systems. It analyzes the regulatory landscape and revenue opportunities for DERs, finding that geographically widespread aggregation models common in other regions are not feasible under Alberta's current regulations. However, business models like retailers' micro-generation rates offer viable pathways for DERs to generate more revenue.

The study highlights the untapped potential for expanding DER participation in various markets and recommends policy changes to support the aggregation of dispersed DERs and their involvement in ancillary services. It also emphasizes the need to optimize incentive allocation across technologies and ensure market signals promote efficient DER use within the distribution network.

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