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ALBERTA ENERGY TRANSITION

DELPHI GROUP

FORESIGHT CANADA

Cleantech Group

With the support of:
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Project Lead on behalf of The Project Consortium:

Kristine O'Rielly
korielly@delphi.ca

DELPHI.ca | 428 Gilmour St | Ottawa ON | K2P 0R8 | T +1 613.562.2005

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EXECUTIVE SUMMARY

The world's energy transition and the technology pathways needed to achieve net zero commitments by 2050 create an opportunity for Alberta to leverage its existing assets and areas of strength in cleantech. A net zero state is achieved when an economy either emits no GHG emissions or off-sets its emissions by removing carbon from the atmosphere through tangible action such as planting trees or employing technologies that can capture carbon before it is released into the atmosphere[1]. Significant opportunities have been identified from this work and spotlight the top priorities for Alberta to participate in the energy transition to reach net zero. These opportunities include:

- Ag-tech (the application of technology to farming operations to optimize operations, reduce carbon footprint, and increase yields)
- Carbon capture, utilization and storage (CCUS)
- Digitalization
- Electrification
- Energy efficiency
- Hydrogen production and utilization

Of the opportunities, energy efficiency, digitalization, and electrification should be further developed in a concerted way to reduce impacts from the energy sector and accelerate unlocking of larger opportunities like hydrogen, CCUS, and ag-tech.

The pursuit of net zero emissions in Alberta is expected to significantly boost jobs and gross domestic product (GDP) compared to a business-as-usual scenario. Based on this study's analysis, pursuing net zero in Alberta could create nearly 170,000 new clean technology jobs and contribute $61 billion in GDP to the province's economy by 2050. For comparison, continuing on a business-as-usual path results in a materially lower 20,000 new jobs and contributes $4 billion in GDP by 2050.

Beyond identifying sectors with competitive advantage, and the size of the energy transition prize for Alberta's future economy, the study went further to identify key requirements and actions needed to fully capitalize on these opportunities.

Capital investment is the key to pursuing a clean energy transition and realizing the associated benefits to environment, jobs, and GDP. Modelling indicates that Alberta will require more than $2.1 billion in capital annually by 2030, growing to as much as $5.5 billion annually in 2040. To achieve this level of capital investment, significant foreign direct investment (FDI) will be needed. Key to attracting this volume of FDI, which will allow Alberta's cleantech ventures to scale up, is strong, consistent climate policy and leadership.

Positive signals are being sent to the investment community that Alberta is prioritizing clean technology development

through strong small business practices and low taxation rates, strong public funding programs for emerging technology and leading research institutions, and test facilities to accelerate commercialization timelines. Industry is also signaling its commitment to decarbonization through the creation of initiatives such as the Oil Sands Net Zero Alliance. Alongside these positive signals, the creation of a dedicated ESG Secretariat demonstrates another important signal to investors on Alberta's commitment to continue being a leading jurisdiction in Environmental, Social and Governance (ESG) performance. Currently the ESG Secretariat is working across ministries towards a holistic government ESG framework that will help showcase how Alberta's government, industry, and institutions are sharpening ESG performance and ensuring investors see the incredible opportunity in Alberta to contribute to achieving a better world, while achieving consistent yields for their shareholders.

Unfortunately, less positive signals are also being sent to investors that may indicate that the energy transition and a serious pursuit of clean technology development are not a priority for Alberta. This includes the cancellation of the Alberta Investor Tax Credit[2], the closure of Alberta's provincial energy efficiency agency – Energy Efficiency Alberta[3] – and the repealing of Alberta's Carbon Tax[4].

[1]See: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html
[2]See: Alberta Investor Tax Credit (AITC) | Alberta.ca
[3]See: Alberta government officially ends agency created to handle green rebates and programs | Globalnews.ca
[4]See: Alberta makes it official: Bill passed and proclaimed to kill carbon tax | CBC News

in emerging technology, such as artificial intelligence and machine learning. The Edmonton region is one of 3 core members of the pan-Canadian AI strategy and has particular expertise in reinforcement learning. Calgary, on the other hand, is building a strong start-up ecosystem that can support ventures across the spectrum of 'cleantech'. Calgary is less hub-focused and instead concentrates on becoming a strong overall innovation ecosystem as witnessed by the fact that currently 70 percent of Alberta's cleantech companies are headquartered in Calgary[5]. It was also ranked as a top 15 cleantech market by Start-up Genome and the second best 'bang for buck' innovation ecosystem in North America[6].

A low-carbon transformation of Alberta's industries and economy will not be without its challenges and will take strong leadership, vision, and resilience to achieve. However, Alberta stands to gain a strong market advantage by developing key clean transition technologies at home. Alberta has considerable technology strengths, energy infrastructure and assets to capitalize on, which also gives the province a unique position in the race to net zero. Alberta's proven track record of using collaboration, capital deployment and resource mobilization to execute large-scale, transformational projects should not be understated. These strengths set the province up to successfully take on its next great challenge: the energy transition.

In tandem with strong and consistent climate policy and FDI, reskilling and training programs for energy sector workers must play a role in this transition and will be critical to mobilize Alberta's clean technology economy. More reskilling and retraining programs are needed, with a clear link to Alberta's clean technology strength areas, such as CCUS and hydrogen. Many energy sector skills naturally lend themselves to the cleantech sector, giving Alberta an advantage when it comes to talent access. Building new skillsets that are currently not present in the province should also be a priority. A renewed focus on bringing new talent to the province will be needed if Alberta is to take a leadership role within cleantech. Alberta's affordable real estate market, high standard of living, and world-class recreation opportunities will be important selling features when attracting top talent to the province.

Alberta's large urban centers have a key role to play in supporting the energy transition, as the in-vestment decisions, talent pool and innovation activity will all be concentrated in these cities. Calgary and Edmonton have taken different approaches in how they capitalize on their respective clean-tech opportunities. However, the cities complement one another and are creating a natural innovation corridor within the province. For example, the Edmonton Metropolitan Region (EMR) is home to Alberta's Industrial Heartland and key energy infrastructure and assets, including refineries and pipeline networks. These assets create a development and deployment area for hard-tech solutions like hydrogen and CCUS. The Edmonton region is also looking to set itself apart from competing jurisdictions by creating deep expertise

[5]See: Startup Genome
[6]Ibid. – indicates that the source is the same as the previous footnote

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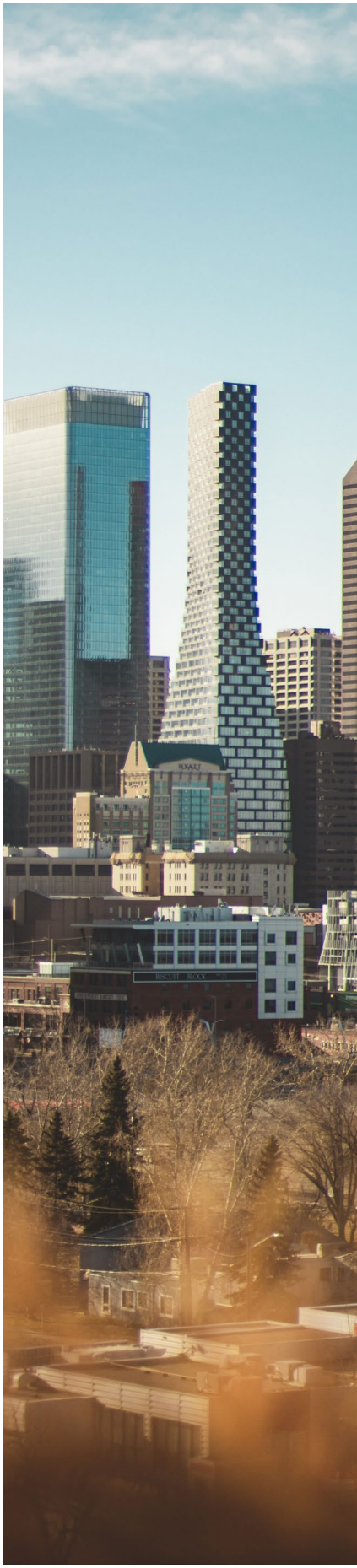


1.0 BACKGROUND

As the energy powerhouse of Canada, Alberta is in a unique position to capitalize on the clean energy transition. This transition will be a time of immense change for Alberta's energy sector and overall economy – driving new infrastructure development, capital investment, and career opportunities. It is prudent to explore how Alberta can best leverage the embedded value of its energy industry infrastructure, talent pool, and capital expenditures to accelerate and amplify transition activities. As Alberta considers further diversification opportunities, it already has many strengths and assets to build from.

In May 2021, Calgary Economic Development (CED) and Edmonton Global (EG), commissioned the Delphi Group, Cleantech Group, and Foresight to conduct an Alberta Energy Transition Study. The purpose of the study is to understand the economic potential of clean technology ('cleantech') in Alberta. Additionally, the study seeks to identify the strengths and differentiators Alberta, Calgary, and the Edmonton Metropolitan Region offer as cleantech development ecosystems to attract foreign direct investment (FDI), talent, and start-up companies to the province.

At its core, this study seeks to help all levels of government and economic development agencies, the business community, community organizations, and Albertans better understand the challenges, opportunities, and key players in Alberta's emerging clean technology sector. This included com-paring Alberta to other clean technology hubs across North America and identifying specific market opportunities in the global energy transition for Calgary and the Edmonton region. The key takeaways from this study will be used as a tool to communicate Alberta's value proposition to potential investors by highlighting these specific market opportunities.

STUDY METHODOLOGY

The study was conducted in two phases. Phase 1 involved painting a holistic picture of the current size and scale of Alberta's clean and emerging technology economy, including key players, support organizations and funding supports. This was done quantitatively through the development of two economic models that quantified current and future cleantech activities – job and GDP contributions – within the province. It also involved qualitative analysis through a SWOT exercise (strengths, weaknesses, opportunities, and threats) and benchmarking to highlight Alberta's cleantech strengths. These strengths were then compared against other cleantech ecosystems globally. Phase 2 applied the findings from the economic analysis, SWOT, and benchmarking activities from Phase 1 to develop key collateral and strategic documents, which will enable CED and EG to articulate the leading advantages of Alberta's clean technology ecosystem and better capitalize on available market opportunities stemming from the energy transition.

CLEANTECH DEFINITION FOR THE STUDY

For the purpose of this study, energy transition cleantech included 16 specific sub-sectors. These sub-sectors were identified and defined in collaboration with CED and EG. The following sub-sectors were included as part of the Energy Transition Study:

- Ag-tech and agriculture
- Carbon capture, utilization, and storage
- Digitalization (IoT, sensors, data analytics, AI, machine learning, AR/VR/digital twins, data management)
- Electrification (including vehicle and rail electrification technologies) and grid infrastructure, including smart grid capabilities
- Energy efficiency (e.g., co-generation, high-performance HVAC equipment, energy management)
- Energy storage technologies, materials, and supply chain (e.g., lithium extraction)
- Hydrogen production and utilization (covers various aspects of hydrogen-related technology including fuel cells, storage, transportation, materials development)
- Methane monitoring and abatement
- Non-thermal use of fossil-based feedstocks and sustainable, alternative and high-tech materials
  - Non-thermal use of fossil-based feedstocks (e.g., bitumen beyond combustion) and sustainable bitumen recovery
  - Sustainable, alternative, and high-tech materials (e.g., biochemicals, bio-plastics, biopharmaceuticals, pipeline coatings, low-GHG cement)
- Renewable energy production
- Small Modular Reactor (SMR) development (i.e., modular nuclear)
- Sustainable fuels
  - Sustainable fuel development, biogas, and renewable natural gas
  - Sustainable fuel development, including transportation fuels (e.g., aviation, biodiesel).
- Waste management and advanced recycling technologies
- Water efficiency and wastewater treatment technologies

It is important to note that as the study progressed, several sub-sectors were combined as it proved challenging to delineate GDP contribution and investment between heavily aligned sub-sectors, particularly for the economic analysis. Renewable natural gas (RNG) and biogas were combined with sustainable transportation fuels to create an overall "sustainable fuels" sub-sector. Similarly, non-thermal use of bitumen (including carbon and bitumen-derived products) and sustainable materials were combined into a single sub-sector as both involved the use of similar infrastructure and feed-stocks to generate value-added products/sustainable alternatives. These sub-sectors have been grouped and sub-bulleted in the list above.

ALBERTA'S CLEAN & EMERGING TECHNOLOGY ECOSYSTEM

1.1 Profile of Alberta's Cleantech Ecosystem

CLEANTECH INVENTORY

An inventory was developed to highlight key financing players and support organizations within the Alberta clean technology ecosystem. The inventory was also intended to provide an overview of the clean technology development activity currently happening in the region. For a company to be included in the cleantech venture inventory, it had to be headquartered in Alberta (or demonstrate the existence of a permanent satellite office), fall within the 16 identified sub-sectors, and demonstrate a link to an environmental benefit through the deployment of the technology/service.

It should be noted that the inventory developed for the study is not meant to be exhaustive, but a representative sample of the cleantech companies, support organizations and financing firms operating in Alberta. The inventory lists were generated from several of sources including the Foresight Alberta bi-annual cleantech survey, Cleantech Group's i3 database and the Start Alberta database.

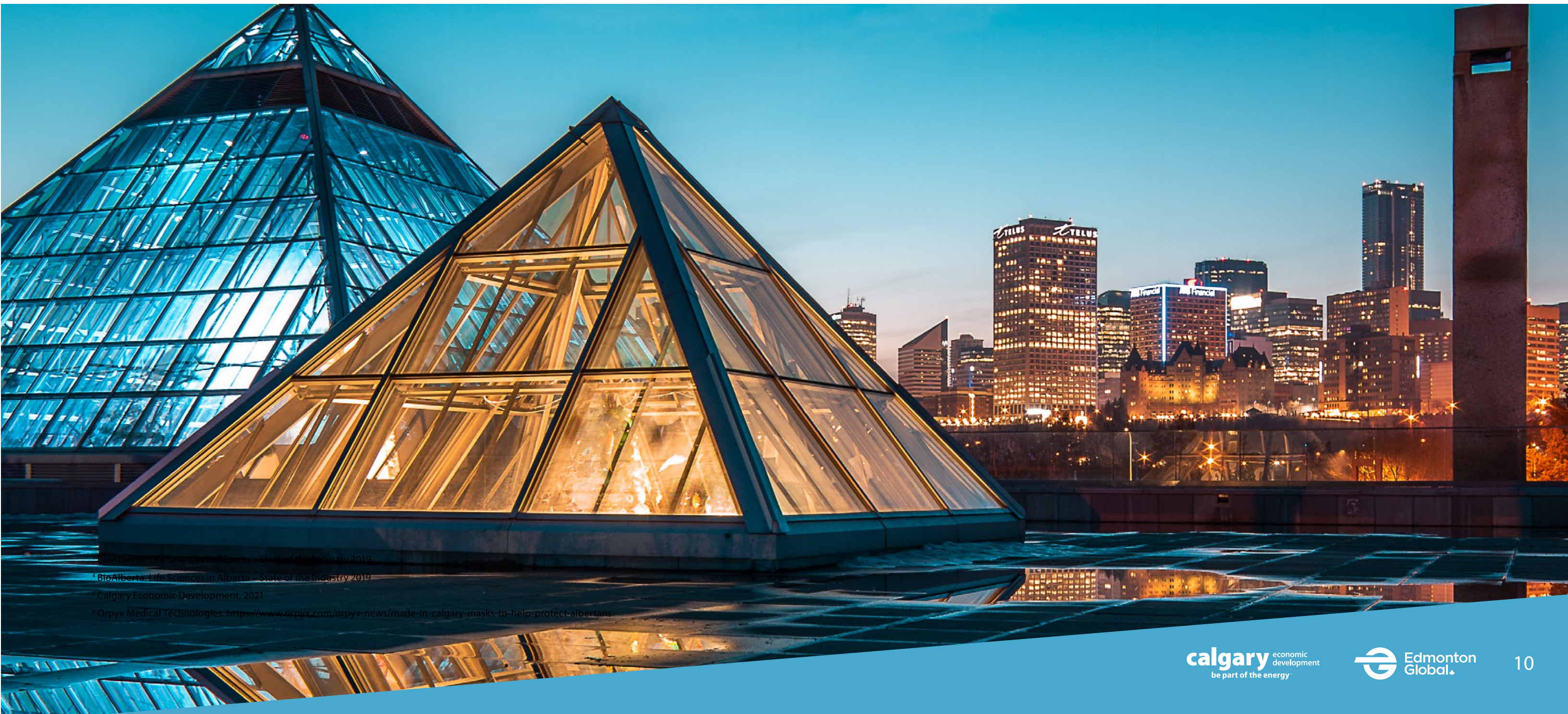
> *From the inventory data, 945 cleantech-focused companies are headquartered in Alberta. The subsectors across Alberta's ecosystem with the largest number of companies include digitalization, renewable energy generation and water efficiency and wastewater treatment, representing areas of strength in talent, expertise and investment attraction.*

A total of 945 companies were included in the cleantech venture inventory, including oil and gas producers working with start-ups and developing technologies in-house. From the inventory data, 462 companies are headquartered in Calgary, while 429 companies call the EMR home. Fifty-four (54) companies are headquartered outside Alberta's two largest urban centers. Broken down, the current leading subsectors across Alberta's ecosystem by number of active companies are digitalization, renewable energy generation and water efficiency and wastewater treatment, representing areas of strength in talent, expertise, and investment attraction. There are also technology clusters developing in the areas of ag-tech, sustainable fuels, methane monitoring and alternative materials/non-thermal use of bitumen.

There were 54 financing entities included in the funding landscape and over 108 organizations were identified as part of the ecosystem support landscape. From the data, it's clear that Alberta is developing a strong clean technology ecosystem, with the programs and facilities needed to accelerate technology development and commercialization. A financial nucleus is also emerging in the province, spurred by growing investor presence and financing activity in Calgary.

CLEANTECH SUB-SECTOR	NUMBER OF COMPANIES (INVENTORY)
Digitalization	131
Renewable Energy Generation	121
Water Efficiency & Wastewater Treatment	59
Non-thermal use of Bitumen & Sustainable Bitumen Recovery	42
Methane Monitoring & Abatement	41
Ag-tech & Agriculture	38
Waste Management & Recycling Technologies	38
Sustainable & Alternative Materials	34
Energy Efficiency	32
Sustainable Transportation Fuels	23
Energy Storage	22
Carbon Capture, Utilization & Storage (CCUS)	13
Hydrogen Production & Utilization	12
Electrification	9
Sustainable Fuels - RNG & Biogas	9
Small Modular Reactors (SMRs)	0

*The inventory also included several ventures under a 'Green Buildings' and 'Transportation' category, as they did not fit within any of the clean technology sub-sectors identified for the project. Consulting organizations that are working to support the energy transition were also included in the inventory under the category 'All', as they tend to work across multiple sectors. They are not ac-counted for in the summary table above. Similarly, some companies fit under more than one category. Companies were classified within the strongest aligning sub-sector.



[3] BioAlberta. Life Sciences in Alberta – State of the Industry 2019
[4] BioAlberta. Life Sciences in Alberta – State of the Industry 2019
[5] Calgary Economic Development, 2021
[6] Orpyx Medical Technologies. https://www.orpyx.com/orpyx-news/made-in-calgary-masks-to-help-protect-albertans

ECOSYSTEM OVERVIEW

An innovation ecosystem can be defined as a geographically bounded and connected cluster of technology-based startups, support service providers, customers, investors, and related entities working together to launch and grow companies. A high-functioning innovation ecosystem includes strong outcomes across the following indicators, according to Startup Genome:

- **Performance**, including access to early-stage funding and customers, the quality of sup-porting infrastructure within the ecosystem, and its capacity to draw entrepreneurs and resources from elsewhere.
- **Talent**, including the accessibility, quality, and cost of relevant expertise and the characteristics of associated Founders such as background, experience, ambition, and approach.
- **Connectedness**, including inter-relationships, collisions, and collaborative support among and between founders, investors, customers, and supporters.

The results of the bi-annual provincial cleantech pureplay venture survey undertaken by Foresight Alberta offer some specific insights into the Alberta ecosystem against these criteria:

> *Pureplay: Describes a company that focuses or specializes solely on one particular product or activity. In cleantech, this could be hardware, software, or service.*

- **Energy industry dominates customer markets, and hardware-based innovation is more-common than digital:** Nearly three-quarters of Alberta's over 210 pureplay cleantech startups seek to sell to the oil and gas industry. Nearly half seek customers in power and utilities, and about one-third in either "other manufacturing", the agricultural sector, or mining. Over two-thirds of ventures are undertaking hardware-based rather than software-based plays, enabled by innovation in chemical process, manufacturing, nanotechnology or genomics. Roughly eight percent of ventures report a focus on carbon capture, utilization and storage (CCUS).
- **Sector is maturing:** Although nearly half of responding companies were under five years old, there are fewer new (less than two years old) cleantech ventures in 2021 compared to 2017 and 2019. Newer ventures move more quickly through Technology Readiness Levels (TRL) than peer ventures started earlier, achieving a higher level of validation.

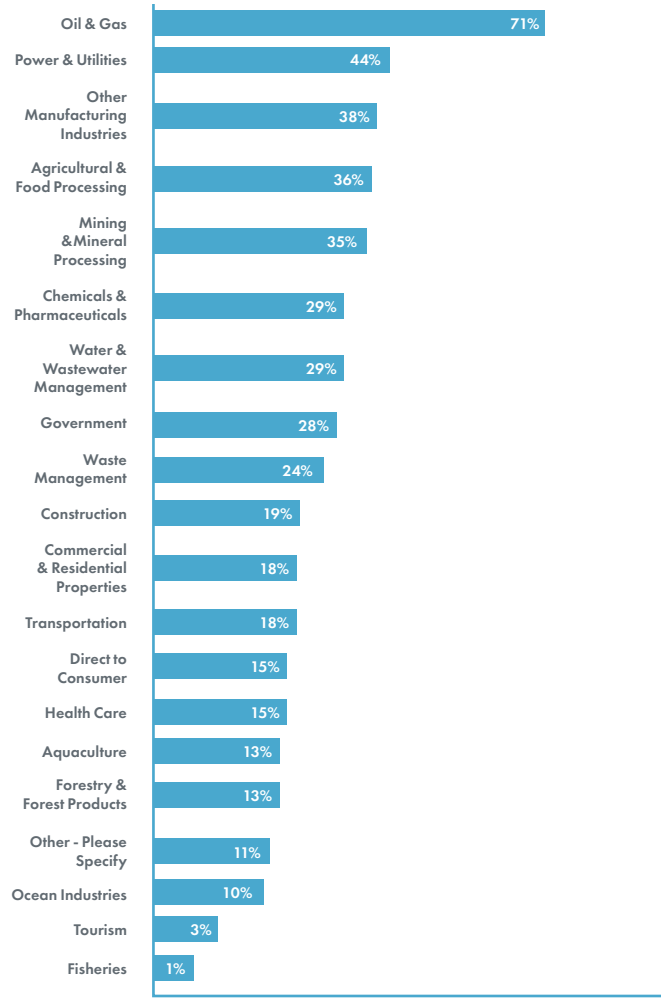


Figure 1: Alberta Cleantech Customers and Target Markets (Foresight Alberta, 2021 Cleantech Report)

- **Founder diversity**: Half of Alberta cleantech ventures (51 percent) are led by first-time founders. Thirty-two percent (32 percent) of ventures have a founder with a trades background. About one-quarter of ventures (28 percent) have founders who were born outside Canada and 22 percent of ventures have a female founder, which is above the national average of 15.6 percent and consistent with the wider Alberta technology development sector.

- **Access to Capital:** Of the roughly 80 percent of ventures who reported seeking public funding and/or private investment, roughly three-quarters were successful. Notably, female founders may face disproportionate barriers in accessing capital. Companies with female founders accounted for only seven percent of the total investment raised by respondents.

Almost half of Alberta's cleantech ventures were pre-revenue in 2019. Close to half of all reported revenue was from Canadian customers, with about one-third from the US and the remaining 22 percent from other global markets. Revenues came primarily in the methane monitoring and abatement subsector. Canadian revenue came primarily from sales in sustainable fuel development, waste management, and advanced recycling technologies.

The COVID-19 pandemic and the associated political and economic actions in 2020 had a significant impact on access to capital and customers. Just over half of ventures reported having lost private debt or equity investment deals as a result of the COVID-19 pandemic. Forty percent (40 percent) reported experiencing a 25-50 percent reduction in revenue year over year, and a third experienced a greater than 50 percent reduction in total revenue.

Primary barriers to commercialization reported by ventures include difficulty getting to a field-based pilot with end-users, as well as identifying and accessing investment capital. The most helpful sources of support identified by entrepreneurs include the Canadian Scientific Research and Experimental Development Tax Incentive Program (SR&ED) and the Natural Research Council's (NRC) Industrial Research Assistance Program (IRAP). Federal granting programs through Natural Resources Canada (NRCan), the federal Clean Growth Hub concierge portal, and support from public agencies including Sustainable Development Technologies Canada (SDTC), Emissions Reduction Alberta, and Alberta Innovates were also cited as beneficial support programs.

Specific strengths or 'connectedness' differentiators within the ecosystem include:

- **Oil and Gas/Transition, (Blue) Hydrogen and CCUS**: The provincial cleantech sector has a relatively high focus on the oil and gas sector and on CCUS. Key innovation networks and non-dilutive funding mechanisms focused in this area include Canada's Oil Sands Innovation Alliance (COSIA), the sector-wide Clean Resource Innovation Network (CRIN) with its associated oil and gas innovation challenges, Emissions Reduction Alberta (ERA), the Petroleum Technology Alliance of Canada (PTAC), Methane Emission Leadership Alliance (MELA) and the Natural Gas Innovation Fund (NGIF). Alberta is also home to four of the world's 30 commercial CCUS projects, the first Carbon XPRIZE, associated test bed facilities, experienced researchers and developers, project regulatory frameworks, and has demonstrated social license for large-scale project deployment, including the construction and operation of the

200 km long Alberta Carbon Trunk Line without any reported public opposition. The new partnership between Avatar Innovations and XPRIZE for a $100M Carbon Removal Competition in support of emerging carbon capture ventures will likely accelerate growth in the density of these ventures in the province.

- **Electricity and Utility Sector**: The province's 'open market' electricity sector is the most dynamic in the country for renewables and energy storage. Specific networks of support include Decentralized Energy Canada (DEC), and the non-utility procurement market-maker Business Renewables Centre Canada. Notably, an emerging geothermal venture cluster includes several companies that have secured global investment.

- **Agriculture:** With an on-farm agricultural carbon offset market in place since 2007, Alberta has transacted over 16 megatonnes (Mt) of compliance-grade nature-based carbon offsets. It is home to several key industrial clusters in the agriculture value chain, including agrichemicals, grain, pulse and beef producer networks, and Canada's Roundtable on Sustainable Beef. Clusters of non-dilutive support backed by industry to drive innovation include the Canadian Agri-Food Automation and Intelligence Network, Protein Industries Canada and Natural Products Canada. Numerous domestic and global investors have established foot-holds and participated in Alberta-based ag-tech deal flow including Builders VC, and Telus Ventures.

ECONOMIC ANALYSIS

The Alberta Energy Transition Study sought to understand the current size and economic contribution of Alberta's clean technology sector through the development of a comprehensive economic model. According to the study's model, the clean technology sector (as defined for the study) em-ployed over 137,000 Albertans in 2020. This number includes all associated cleantech jobs – direct, indirect, induced, corporate development, etc. – across the sub-sectors. This number represents 6.3 percent of Alberta's total job count, or 139,000 out of 2.2 million in 2020.

> *Alberta's cleantech sector employed over 137,000 Albertans in 2020. This number includes all associated cleantech jobs – direct, indirect, induced, corporate development, etc. – across the sub-sectors, representing 6.3percent of Alberta's total job count (2.2 million in 2020).*

The study also sought to understand the number of direct jobs associated with the cleantech sub-sectors. From Figure 2, the top five sub-sectors for direct technology jobs in Alberta are 1) Energy efficiency (3524), 2) Waste management (2449), 3) Sustainable fuel development (1406), 4) Non-thermal use of bitumen and sustainable materials (1386), and 5) Ag-tech and agriculture (1270). It is important to note that not all direct jobs are created equal. For example, most energy efficiency jobs identified via NAICS codes are likely to be deployment activities (e.g., installation of energy efficient technologies), while jobs in sustainable fuel development are focused on production technology and processes.

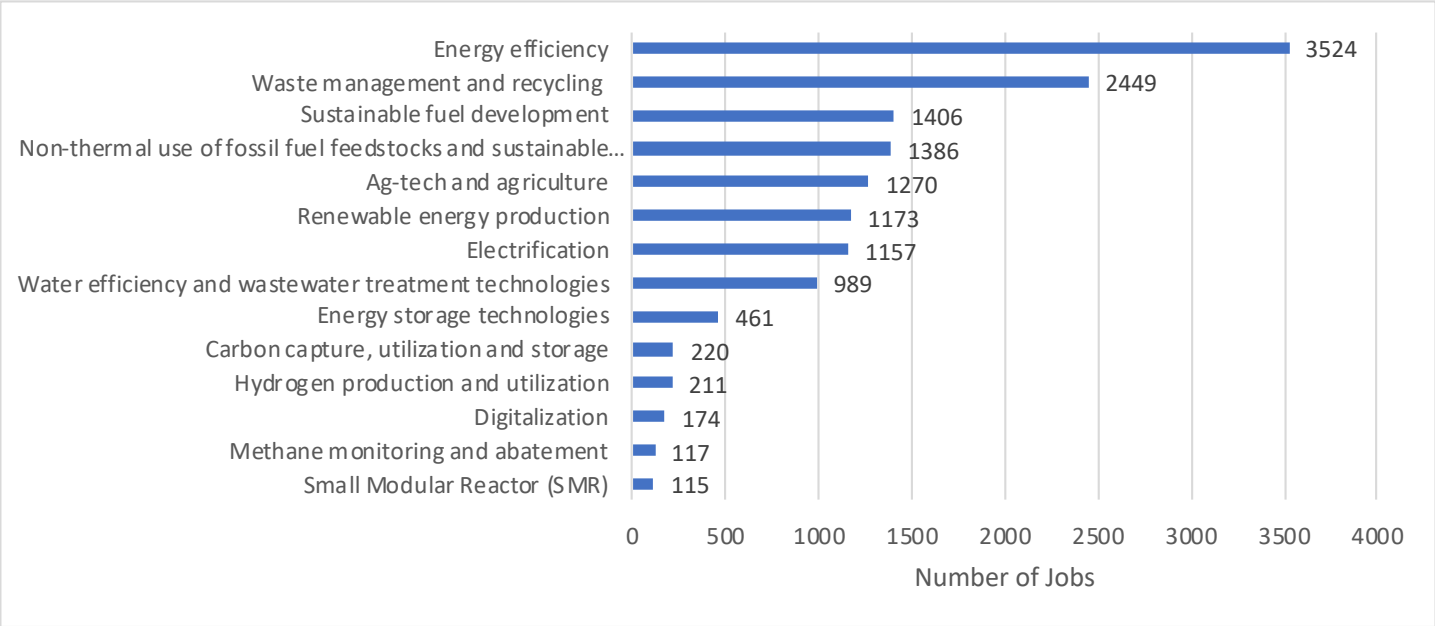


Figure 2: Direct Technology Jobs by Cleantech Sub-sector, Alberta 2020

The economic model also analyzed the current market size (i.e., GDP) generated by each clean technology sub-sector, with direct technology GDP contributions tabulated for each. While Figure 3 below captures direct GDP, each sub-sector will also contribute spillover benefits and economic activity – both indirect and induced GDP – beyond clean technology focused activity. This speaks to the need to look holistically at cleantech opportunities to ensure all economic benefits are well understood so that growth opportunities can be identified and captured. When considering direct technology activities only, the top five sub-sectors include water efficiency and wastewater, energy efficiency, sustainable fuel development, renewable energy, and waste management.

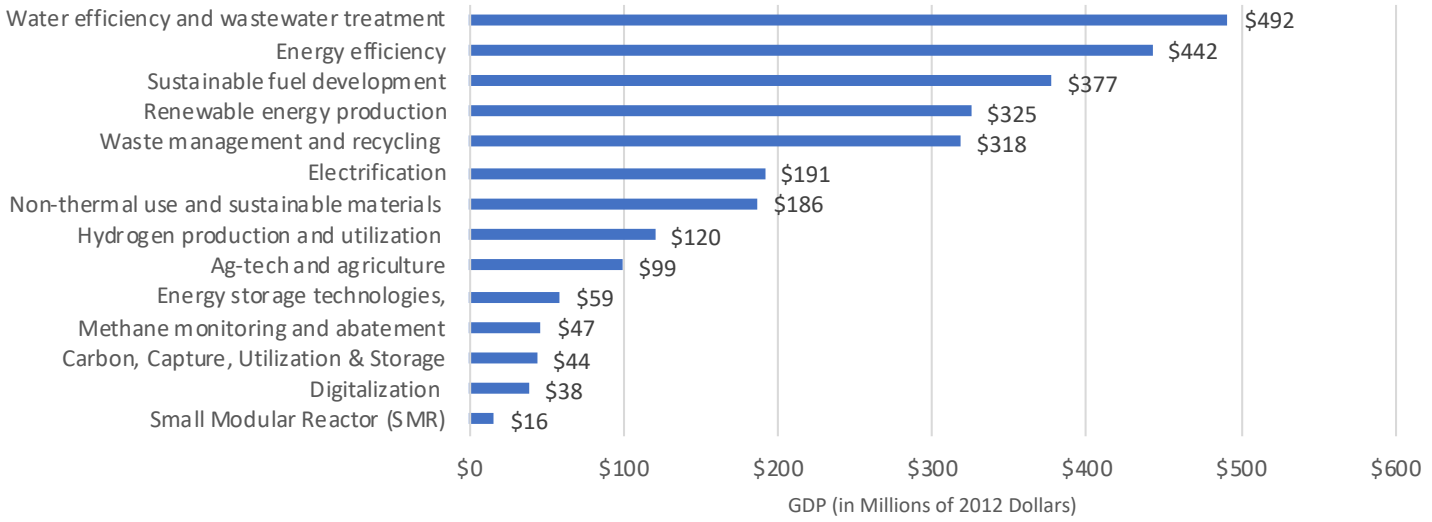


Figure 3: Direct Technology GDP by Cleantech Sub-sector, Alberta 2020

EMPLOYMENT CHARACTERISTICS

Worker characteristics of clean technology jobs reported by Statistics Canada, shows that 24percent of the jobs in the sector have a university degree or higher, 25percent have a college diploma and 17percent have a trade certificate[7]. Looking to the Environmental and Clean Technology (ECT) sector, the annual average salary of this profession was $112,067 for men, and $105,312 for women, which is slightly above the annual average salary for a similar position outside the cleantech sector - $102,254. Thus, bringing new clean technology positions to the province can provide stable, well-paying employment to Albertans – particularly those impacted by a downturn in the oil and gas sector.

Insights on key cleantech occupations in the sector can be drawn from a 2020 ECO Canada report, which concludes that the cleantech workforce requires workers with both highly specialized skills such as a chemical engineer or technologist, and business acumen, such as financial managers[8], logistics experts, and accountants. The report also stated that many employers are currently struggling to fill certain cleantech positions, including:

- Engineers, drafters, designers, and technicians
- Geologists, laboratory specialists, environmental technicians, scientists
- Project managers, directors
- Trades (Welders, electricians, mechanics, and others)
- Drivers, machine operators.

In asking the question of what this economic shift means for Alberta's workforce within an energy transition, the answer is clear. The shift will create economic benefit and increase Alberta's share of Environmental and Clean Technology sector jobs, which are more stable.

To further strengthen Alberta's clean technology economy, a focus on upskilling and reskilling workers for cleantech positions, like those listed above, will be needed to ensure Alberta's future workforce can meet demand for cleantech skillsets. Reskilling and training programs for energy sector workers must play a role in this employment transition. Many energy sector skills naturally lend themselves to the cleantech sector, which means that Alberta has an advantageous position when it comes to talent access. Bringing in new skillsets, not currently present in the province, should be a priority. Alberta's affordable real estate market, high standard of living and world-class recreation access will be important selling features when attracting top talent to the province.

Figure 4 below indicates that cleantech job seekers are forecast to be greater than job openings in 2025 and 2030 on average. In 2025 the imbalance of job seekers over openings is 5,085 or 7.2 percent, By 2030, the imbalance will have declined significantly to 1,713 or 2.3 percent. This is an important indicator for cleantech companies looking to relocate or grow in Alberta, as there appears to be a ready and willing labour force for clean technology development in the province. However, there is nuance to this overall number, as certain subsectors may have more trouble finding skilled employees than others. Of specific interest is the CCUS sub-sector that looks to be facing a shortage by 2030. Contrast this with hydrogen and energy storage, where modeling anticipates a strong supply of job seekers. The implication is that reskilling, upskilling and/or talent attraction in the province should focus on sub-sectors that are facing tight labour markets to ensure economic growth potential can be achieved.

[7]See: Portrait of Environmental and Clean Technology Jobs
[8]See: Cleantech Defined: A Scoping Study of the Sector and its Workforce

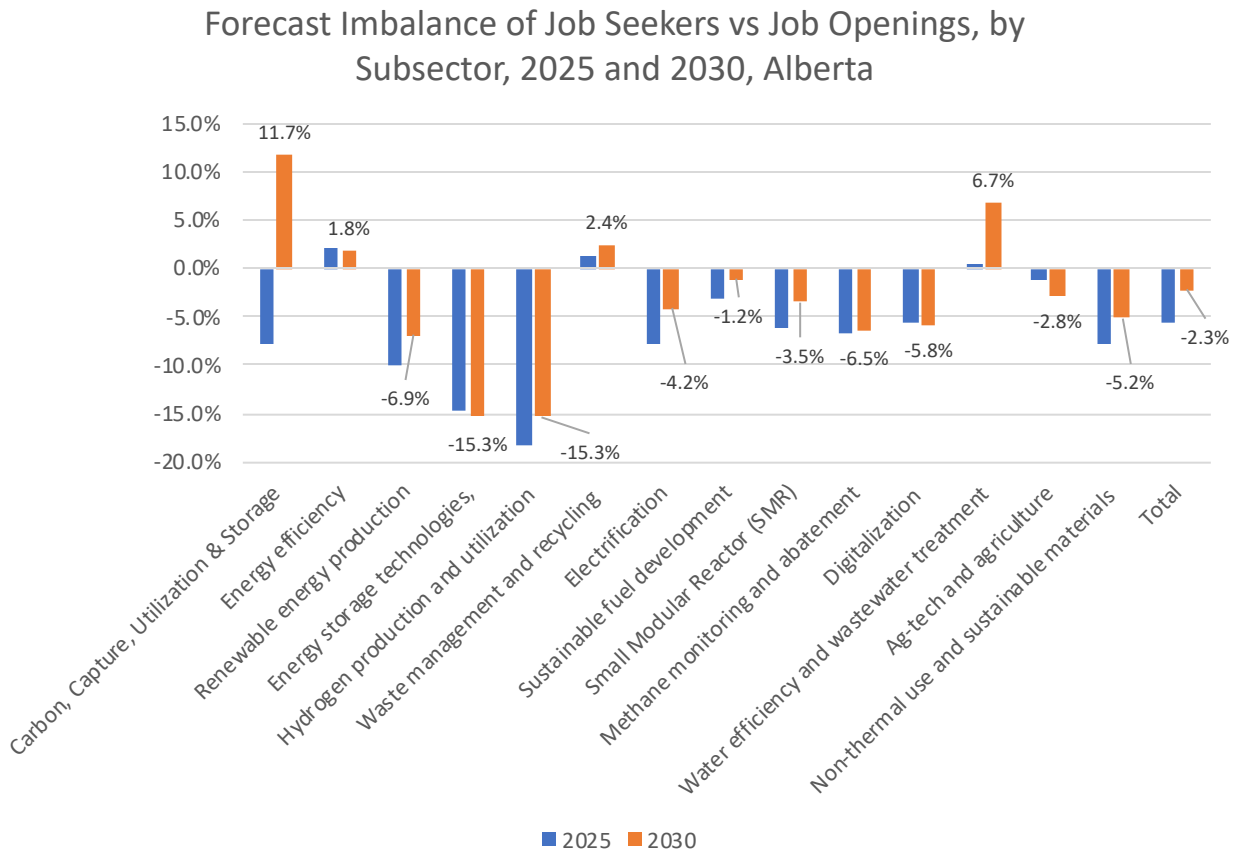


Figure 4: Forecast Imbalance of Job Seekers vs Job Openings, by Subsector, 2025 and 2030, Alberta[9] [10]

FUTURE MARKET GROWTH ANALYSIS

Following the development of a baseline economic model, designed to give an overview of the status of the clean economy in Alberta, a future-facing model was developed to identify cleantech sub-sectors with the highest potential economic impact.

The future market growth assessment compared the GDP contribution and job potential of a net zero trajectory in Alberta against a 'traditional' growth forecast. The traditional forecast was based on the Occupational Outlook 2019-2028 for Alberta, a long-term assessment of potential imbalances in the provincial labour market developed by the Department of Labour and Immigration in October 2019. The net zero trajectory was developed using annual growth rates from a variety of sources, including the International Energy Agency (IEA), Alberta Electrical System Operator (AESO), Navius Consulting, SNC Lavalin, Bloomberg and McKinsey. Further information on the growth rates can be found in the Appendix.

For this analysis, the forecast was extrapolated out to 2050. Figure 5 below highlights the significant job market opportunities that could result from investing in a net zero future in Alberta, compared to a traditional or 'business-as-usual' scenario in terms of investment priorities. Figure 6 demonstrates GDP growth comparisons between the two scenarios – cleantech (net zero trajectory) vs. traditional. By 2050 the net zero growth scenario could generate almost 170,000 clean technology jobs and contribute $61 billion in GDP. In contrast, the 'business-as-usual' pathway would only generate 20,000 new jobs and $4 billion in GDP by 2050, assuming outlook period (2019-2028) growth trends continue.

[9]Source: Alberta's Occupational Outlook 2019 - 2028
[10]Proportion of net job seekers is defined by openings minus seekers as a ratio of total job seekers

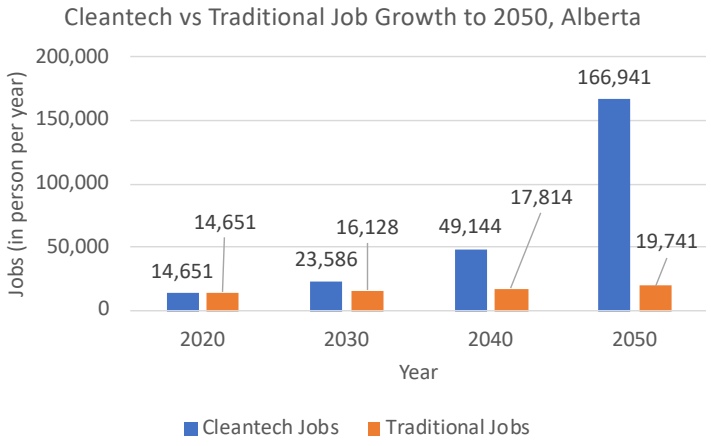


Figure 5: Cleantech vs. Traditional job growth in Alberta to 2050

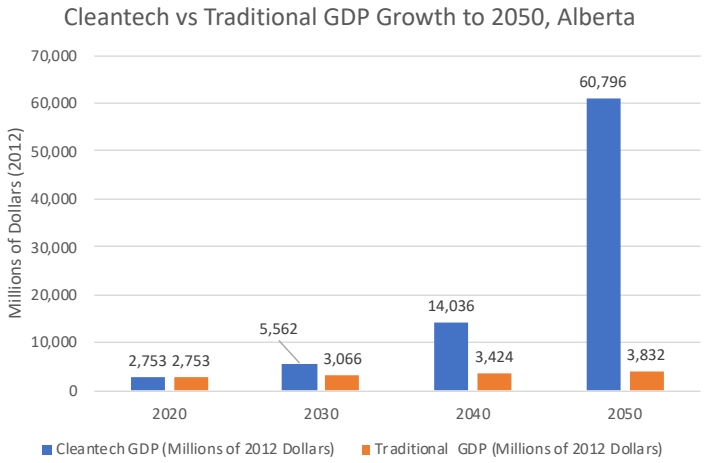


Figure 6: Cleantech vs. Traditional GDP growth in Alberta to 2050

The net zero scenario analyzed the investment required across the clean economy and across clean technology verticals for Alberta to remain on an emission-reduction trajectory, as well as the subsequent jobs and GDP contributions that would result from this investment. According to the analysis, the top 5 performing clean technology sub-sectors, in terms of job growth, between 2020 and 2030 are:

1. Sustainable fuel development
2. Energy efficiency
3. Non-thermal use of bitumen and sustainable materials development
4. Waste management
5. Renewable energy production.

The top 5 performing clean technology sub-sectors in terms of GDP contributions by 2030 were as follows:

1. Sustainable fuel development
2. Water efficiency and wastewater treatment
3. Energy efficiency
4. Non-thermal use of bitumen and sustainable materials development
5. Renewable energy production.

MODEL LIMITATIONS

The job and GDP contributions by sub-sector were developed out to 2030, 2040, and 2050. The predictive accuracy of the model will begin to diminish beyond 2030, given the regulatory and policy uncertainty of the identified technology sub-sectors, such as small-modular reactors, hydrogen, and electrification. It should also be noted that the model has been developed in such a way that it builds off existing job and GDP data (e.g., Statistics Canada data). This means that certain sub-sectors will have a higher job count at the outset of the analysis. Emerging sub-sectors with lower current job counts, but higher growth rates, such as digitalization, carbon capture utilization and storage, energy storage and hydrogen, may not have time to 'catch-up' to more established sub-sectors out to 2030, even though they are growing at a much faster rate.

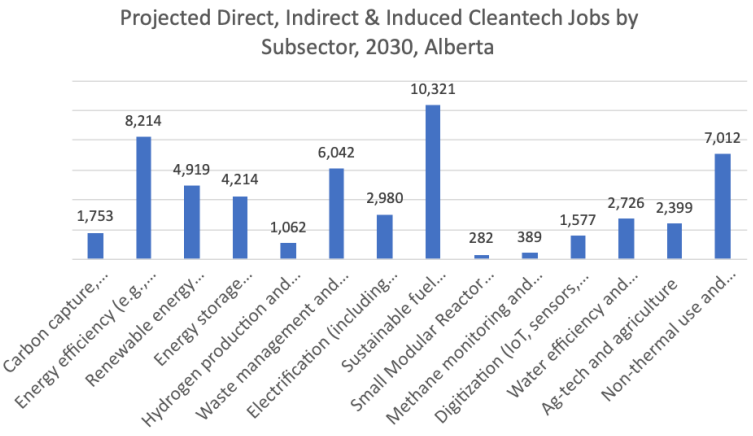


Figure 7: Projected direct cleantech jobs by sub-sector in Alberta by 2030

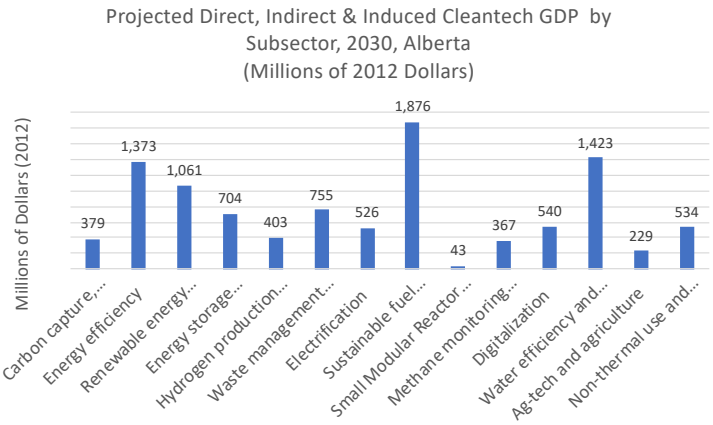


Figure 8: Projected direct clean technology GDP by sub-sector in Alberta by 2030 (Millions of 2012 Dollars)

If Alberta is to reap the benefits of clean economy-related jobs and economic activity, the analysis suggests that a significant level of new capital will need to be invested. A previous Alberta-focused cleantech study developed by Navius Research was reviewed and used as a source for the future market growth analysis.

The Navius study showed that every dollar of capital investment in the clean economy would yield $2.90 in GDP in 2020. By 2030, this ratio is expected to be $2.54 because of the cleantech 'learning curve' or productivity gains within emerging clean technology markets. The same phenomenon applies to job creation. For example, in 2020, every million dollars in cleantech capital investment yielded 19 cleantech jobs. By 2030, this multiplier is 14.6 jobs per million dollars in capital investment. This ratio was used to guide the development of the future market assessment for this Alberta Energy Transition Study.

By breaking down the data around investment dollars in cleantech sub-sectors and economic growth, the numbers revealed a compelling takeaway which is that cleantech investments would not only put Alberta on the road to a lower-carbon future but would also kickstart significant economic growth. The study's modeling found that to capitalize on the clean energy transition, Alberta will need to invest more than $2.1 billion annually in the cleantech sector by 2030; and this amount will increase to $5.5 billion by 2040. This growth versus investment comparison is highlighted in Figure 9 below. The investment leverage – or the net GDP gain from cleantech investment – is indicated by the yellow-shaded area in Figure 9.

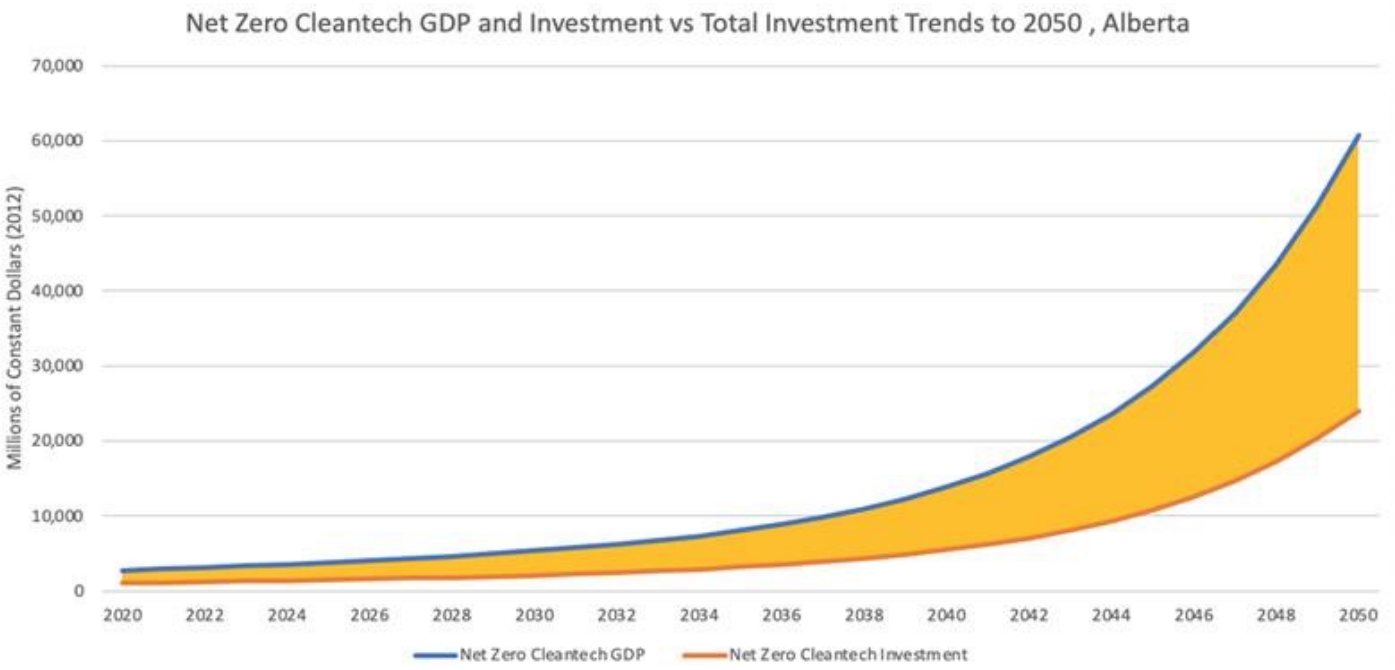


Figure 9: Clean technology generated GDP vs. required investment through to 2050 in Alberta

1.2 SWOT & Gap Analysis

PRIORITIZATION MATRIX

A prioritization exercise was undertaken to determine which sub-sectors could offer the greatest clean technology opportunities to Alberta. The six highest-potential sub-sectors were identified from the list of 16 developed at the outset of the project. Each sub-sector was scored against a common set of evaluation criteria, which included the following areas (criteria weighting shown in brackets):

- Short-term opportunities (3 percent): Commercialization potential within 1-5 years.
- Demonstrated industry interest and demand (15 percent): Active pilot projects, large-scale demonstration of the technology, industry accelerator/incubator sponsorship, direct industry investment in start-ups and scale-ups.
- Policy drivers or barriers (5 percent): Sub-sector specific policies or regulations in place to support or improve the likelihood of technology uptake or investment attraction.
- Current market size (12 percent): Current market size (GDP in millions of 2012 dollars) output from the baseline economic model.
- Strength of support ecosystem and infrastructure (8 percent): Includes funding programs, test facilities, laboratories, industry associations and networks, accelerator and incubator programs focused on specific clean technology sub-sectors.
- Sector maturity (8 percent): Average age of cleantech ventures, sophistication of policies and regulations, industry strategies focused on the sub-sector.
- Job creation (12 percent): Number of jobs generated by the baseline economic model.
- Medium and long-term opportunities (12percent): Anticipated commercialization and deployment potential beyond the next 5 years. Annual growth potential of the sub-sector.
- Global interest/foreign direct investment (FDI) potential (15 percent): Indicators that the technology sub-sector would be deployed by other markets and draw interest from international investors.
- Export potential (12 percent): Export-focused data from the baseline economic model; based on 2020 values.
- Future job projections (12 percent): Average of 2030, 2040, 2050 job projections as determined by the future market growth assessment net zero pathway model.
- Future GDP contribution projections (12 percent): Average of 2030, 2040, 2050 GDP contributions (millions of 2012 GDP) as determined by the future market growth assessment net zero pathway model.

Secondary research was conducted across the evaluation areas cited above for each of the 16 cleantech sub-sectors identified for the project. Examples demonstrating current activity and potential opportunities, along with economic model outputs, were organized in a matrix format. The project team used an established rubric to score each cleantech sub-sector across all evaluation criteria.

The exercise also took into consideration the development versus deployment potential of the sub-sectors. For example, renewable energy projects will play an important role in Alberta's clean energy transition, however the likelihood of new technologies (e.g., higher efficiency solar panels, upcycled wind turbines) being developed in Alberta are low; it is more likely that renewable energy will provide deployment opportunities and projects in the province rather than a renewable energy start-up ecosystem.

The scoring also took into consideration Alberta's ability to lead across each sub-sector through the utilization of existing infrastructure and assets, leveraging the province's current skilled energy workforce and leveraging the deep expertise Alberta has in energy, agriculture and forestry. In this regard, some sub-sectors did not score well overall, despite having relatively higher economic contribution – jobs, GDP and export revenue. Focus was put on future growth rates of the technology sub-sectors. It is expected that many energy transition focused technology areas will begin to outgrow traditional energy sector service industries, such as waste management and wastewater treatment, by 2025. Similarly, some sub-sectors did not complement Alberta's energy transition strengths or are already seeing considerable market saturation from other jurisdictions. These lenses were taken into consideration when selecting the highest-potential technology sub-sectors to focus the study's SWOT and benchmarking analyses on.

The results of this exercise are interesting, as they significantly alter the potential sub-sectors of focus. As with any transition, it becomes evident that the path forward will require more attention to be spent on new and emerging opportunity, rather than emphasizing historical or 'business as usual' sectors. Greater opportunity for success will be found in fostering sub-sectors with greater growth potential and stronger strategic advantage.

A detailed profile of the six prioritized sub-sectors can be found in the Appendix. The top six identified sub-sectors, in alphabetical order, are as follows:

1. Ag-tech and agriculture
2. Carbon-capture utilization and storage
3. Digitalization
4. Electrification
5. Energy efficiency,
6. Hydrogen production and utilization.

While not in the list of the top six, the authors wish to make a note below of two additional categories that are expected to play a significant role in Alberta's energy transition.

RENEWABLE ENERGY GENERATION

This sub-sector is intrinsically linked to several other clean technologies, including electrification and energy storage. The pace at which Alberta can bring additional renewable energy capacity online (currently electricity in the province is over 91 percent fossil-fuel generated[11]) will impact its ability to attract start-ups working on certain energy transition pathways, like electrification. Alberta has significant renewable energy potential, with one of the best solar resources in Canada[12] and the potential for 150 GW (giga Watts) of wind generation and 120 GW of geothermal generation[13] – which would far exceed Alberta's current power needs (~15 GW). However, with the exception of geothermal, renewable energy technologies are considered a mature product with an established global supply chain. As such, renewable energy is likely to represent a deployment effort in Alberta, rather than a cleantech development opportunity. In light of this, a deeper dive into this sector was not pursued.

SUSTAINABLE FUEL DEVELOPMENT

Alberta's energy sector infrastructure, talent pool and feedstocks align well to this sub-sector. Sustainable fuel technologies are mature within the province and offer significant opportunities. Emerging pathways in the sustainable fuels space include the utilization of Alberta's forestry sector residual waste to generate transportation fuels and the development of sustainable aviation fuel (SAF). Significant policy and regulatory barriers still exist in the SAF space, although it is emerging as a clear priority for the airline industry. The implementation of the federal Clean Fuel Standard[14] will also drive activity and increased need for sustainable fuels.

The use of sustainable transportation fuels beyond 2035 is in question as the focus is shifting toward the electrification of personal vehicles, although a market for diesel displacement for remote communities and heavy industry vehicles is likely to remain. For this reason, sustainable fuels scored lower in the long-term opportunities category compared to other technology pathways. However, over the next five to ten years the opportunity within the sustainable fuels industry will remain high for Alberta and should remain an investment priority.

SWOT ANALYSIS METHODOLOGY

A SWOT analysis was undertaken to better understand (and verify) the current state of the clean technology ecosystem in Alberta and to identify the opportunities and threats that exist for successful clean technology development within the province. It was developed using a combination of secondary desktop research and a series of key informant interviews.

The SWOT analysis was conducted in two separate parts:

1. A SWOT analysis of the overall Alberta ecosystem, including available supports, programs, policies and funding mechanisms.

2. An individual SWOT analysis for the six prioritized clean technology sub-sectors, highlighting potential opportunities and areas for improvement needed to drive additional activity within each sector.

[11] Source: CER – Provincial and Territorial Energy Profiles – Alberta (cer-rec.gc.ca)
[12] Source: Photovoltaic potential and solar resource maps of Canada (nrcan.gc.ca)
[13] Source: Alberta's green energy future | Corporate Knights
[14] Source: Clean Fuel Standard regulatory design - Canada.ca

SWOT ANALYSIS — ALBERTA'S CLEANTECH ECOSYSTEM

STRENGTHS

The growth of Alberta's cleantech sector presents significant opportunities to achieve net zero emissions and sustainable economic growth. Robust public funding and cleantech development programs,[15] coupled with key commercialization laboratories and test centers, are driving rapid progress in the sector. Specifically, funding programs from Emissions Reduction Alberta, and Alberta Innovates, in part supported by carbon compliance revenues from the Technology and Innovation Emissions Reduction Regulation (TIER), has been an important differentiator in setting the sector up for success.[16]

Foresight Alberta's 2021 Cleantech Report highlighted new ventures are more rapidly progressing through Technology Readiness Levels (<10 years) compared to historical timelines.[17] Favorable corporate tax rate,[18] wide availability of public grants,[19] along with strong entrepreneurial spirit have been instrumental in attracting new streams of cleantech investment to the region. Organizations like De-centralized Energy Canada and Canadian Environmental Technology Advancement Corporation-WEST have been the backbone of the ecosystem by providing a range of support such as mentorship, networking, and policy advocacy support.[20]

Alberta's skilled, and diverse workforce is a core asset, with a growing share of workers receiving postsecondary certificates and university degrees.[21] Alberta has the most engineers per capita in Canada.[22] In 2018, it was estimated that there were 8.9 engineers per 1000 people in Alberta, which is almost twice the national average. Low cost of living and livability of the region[23] continue to be strong selling features for attracting new talent.

WEAKNESSES

Despite the strengths of Alberta's cleantech sector, barriers continue to slow growth. A lack of consistent policy and regulatory drivers for technology adoption,[24] as well as a narrow focus of financing mechanisms[25] hinder mass commercialization efforts. These mechanisms have primarily focused on supporting start-ups, rather than helping established SMEs achieve market expansion and/or pivoting into cleantech areas. SMEs developing non-oil and gas technologies tend to be overshadowed by the traditional hydrocarbon-based companies,[26] which limits potential for global markets and offtakers.

Higher labour costs and difficulty reaching economies of scale continue to pose challenges for Alberta to scale up and compete with global manufacturing centers[27]. Other key barriers include connection to first buyers,[28] corporate partner red tape,[29] as well as a lack of carbon pricing and regulatory certainty domestically, and with key trading partners, driving overarching net zero or decarbonization targets and associated investments.[30]

[15] Source: Globe Series - Emissions Reduction Alberta: Successfully Scaling Cleantech
[16] Source: SWOT Interview
[17] Source: Foresight Alberta 2020 Cleantech Report
[18] Source: Canada ranks 1st among G7 countries for ease of paying taxes and low total tax burden for small to medium-sized companies
[19] Source: Government of Alberta - Supports for technology businesses
[20] Source: SWOT Interview
[21] Source: Alberta's Labour Market Highlights 2019
[22] Source: Engineers Canada – 2019 National Membership Information
[23] Source: Government of Alberta - Life in Alberta
[24] Source: Foresight Alberta 2020 Cleantech Report
[25] Source: SWOT Analysis Advisory Committee
[26] Source: 2018 Cleantech Directions: Spotlight Alberta Report
[27] Source: SWOT Interview
[28] Source: Foresight Alberta 2020 Cleantech Report
[29] Ibid.
[30] Source: SWOT Analysis Advisory Committee

OPPORTUNITIES

Significant opportunities exist to accelerate the development of Alberta's cleantech ecosystem. The strong desire to drive innovation in the Alberta entrepreneurial community, particularly in the Calgary region, as noted through the study's stakeholder engagement process, (e.g., Rainforest Alberta, Central Alberta Regional Innovation Network [CARIN], Clean Resource Innovation Network [CRIN]), provides an opportunity to develop an innovation culture across the province, and promote a more collaborative, complementary overall ecosystem.[31]

Sustainability and climate commitments at the executive leadership and senior management level are needed to provide clear direction towards a grander cleantech vision and strategy for Alberta's heavy industry.[32] Strong signals from Alberta's corporate community will help solidify the region as a preferred location for cleantech development and investment. Additionally, government and crown corporation first-buyer programs and non-prescriptive, green procurement strategies[33] can accelerate the adoption of new emerging technologies.

Policy and funding mechanisms from government can be designed to help the sector expand by providing support for existing companies to pivot or diversify market offers. Implementing sustainable financing criteria and a border carbon tax can potentially help Alberta to achieve its net zero targets, and thus bolster growth in the cleantech sector.[34] Indigenous participation can also bring in valuable insights and access to federal funding and partnership to projects.[35]

[31] Source: SWOT Interview
[32] Source: SWOT Analysis Advisory Committee
[33] Source: Canada launches clean electricity procurement process, with emphasis on Alberta solar
[34] Source: SWOT Interview
[35] Ibid.
[36] Ibid
[37] Source: SWOT interview
[38] Source: Foresight Alberta 2020 Cleantech Report
[39] Ibid.
[40] Source: SWOT interview
[41] Source: Global News - Initiative aims to determine what it will take to keep young people from leaving Calgary and https://www.cbc.ca/news/canada/calgary/young-albertans-leaving-the-province-1.6208420
[42] Source: SWOT Analysis Advisory Committee

THREATS

The progress of Alberta's cleantech ecosystem may be hindered by several external factors. With the rapid progress in technologies, "new-tech" of today may quickly become outdated.[36] This is often known as the 'leapfrog' effect, in which industries or jurisdictions who are late to implement solutions by-pass technologies focused on incremental change and wait for game-changing innovation. This phenomenon is not unique to cleantech but drives home the importance of investing in the development of both incremental and game-changing technologies to maintain a leadership advantage.

From a policy standpoint, there is no unified or clear policy directives towards an overarching net zero or decarbonization target, resulting in the continued fragmentation of Alberta's cleantech and action toward net zero. Policy uncertainty[37] (e.g., Energy Efficiency Alberta cancellation, coal phase-out hesitation) and cancellation of investment mechanisms[38] (such as Investor Tax Credits)[39] with changes in provincial or federal government are contributing to an uncertain investment environment.

Stronger provincial policy and investment mechanisms are necessary to incentivize the local and global investment community. Dampened government royalties and revenues from corporate and personal income taxes may threaten the sources of funding programs;[40] which may be detrimental to the growth of the overall ecosystem as companies are heavily reliant on funding programs. Collectively, flight of young, skilled labor from city centres,[41] decreased funding of universities, lack of participation in childcare subsidies, and diversity and inclusivity issues threaten the future talent pool for those in the high tech, energy, and technology space.[42]

SWOT ANALYSIS — AG-TECH

STRENGTHS

The evolving ag-tech sector in Alberta is driven by deep agribusiness expertise and emerging digital solutions in the region. Alberta has established itself as a large net exporter of food commodities[43] supported by federal and provincial programs and policies (such as Canadian Agricultural Partnership, Smart Agriculture and Food Digitalization and Automation Challenge and Canadian Agri-Food Automation and Intelligence Network funding). Its geographic proximity to the largest trade partner, i.e., U.S., has also been critical in establishing its strong export market.

Albertan farmers have been early adopters of productivity boosting technologies, such as precision farming, which has been well-deployed and well-utilized. Increased local and global consumer demands, coupled with labour shortages and supply chain disruptions, present huge opportunities to integrate in-farm automation to scale up agricultural capabilities. Institutes such as Olds College, the University of Lethbridge, University of Alberta, and Lethbridge College offer unique agricultural programs, supporting strong technical capacity-building across the supply chain.[44]

WEAKNESSES

Adoption of new technology has slowed due to barriers such as large upfront investment, and return-on-investment uncertainties.[45] Technologies come with a steep learning curve, and uptake can be hampered by a lack of basic digital literacy,[46] general risk aversion,[47] especially among the older generation of farmers. The siloed nature of agribusiness further prevents mass knowledge exchange and collaboration across the value chain.[48] Without core digitalization skills and industry-wide collaboration, the adoption cycle may die a "quick death".

Reskilling and mentorship programs[49] can train farmers in digital literacy by connecting them with peers who possess both agricultural and digital knowledge (e.g., intergenerational mentorship programs). In terms of government policies, a more holistic and forward-looking perspective is lacking for jurisdictional land development and the future of food security.[50] Such policy consideration is critical to enable the emergent sector to jump-start and compete with the major global producers with similar or more advanced ag-tech verticals.

OPPORTUNITIES

Beyond mere productivity gains, ag-tech verticals introduce a myriad of opportunities for the agribusiness sector and farmers. Digital agriculture monitoring can help farmers to see beyond a myopic view on production and take sustainability considerations into account.[51] The agriculture sector is one of the largest producers of greenhouse gas emission, thus carbon offsets and the carbon marketplace could complement the agricultural (and forestry) technologies, to create strategies towards a low carbon economy.[52] This study found that, by 2030, the ag-tech sector could employ 2,400 people and contribute $229 million to Alberta's GDP.

Canada can form targeted policies similar to the recent U.S. Agriculture Innovation Agenda initiative, to reduce the environmental footprint of its agricultural sector.[53] There is also an opportunity to develop irrigation and surveillance technologies within the province that will not only improve its water efficiency but also allow it to export technologies to jurisdictions experiencing similar climate impacts.[54]

THREATS

Lagging internet connectivity[55] in rural areas coupled with cybersecurity and data ownership[56] concerns may cause disruptions in the ag-tech sector. Government investments will be required to ensure reliable and fast internet connection to farms. The province will require updates on intellectual property laws to integrate data ownership associated with ag-tech.

The sector also faces a looming threat of a knowledge vacuum, as it heads into a retirement cliff in the next decades.[57] Earlier integration of agriculture, starting in K-12 schools, can provide a significant opportunity for attracting younger talent.[58]

The agri-food system also remains vulnerable to COVID-19 related import restrictions, and exogenous shocks in the U.S. agricultural market.[59] The current adoption of digital technologies are driven by the needs of large-scale corporate farms, which can be detrimental to the participation of small-scale and medium-sized farms in the long run.[60] These factors may inhibit the growth and success of the Albertan ag-tech industry to compete in the global market.

[43]Source: CED Agribusiness Market Study
[44]Ibid.
[45]Source: Alberta Farmer Express - Pandemic speeding up adoption of technology
[46]Source: Rural broadband policy recommendations for improving broadband access & adoption in rural Alberta
[47]Source: The Ag-tech Adoption Dilemma: Irrigation
[48]Source: CED Agribusiness Market Study
[49]Source: RBC Though Leadership – Farmer 4.0
[50]Source: SWOT Analysis Advisory Committee
[51]Source: Food Agility - What are the social drivers and barriers to ag-tech adoption in Australia?
[52]Source: SWOT Analysis Advisory Committee
[53]Source: Five key issues facing Canada's agri-food industry
[54]Source: SWOT Analysis Advisory Committee
[55]Source: Agriculture 4.0: The Canadian Ag-tech Ecosystem
[56]Source: CED Agribusiness Market Study
[57]Source: CountryGuide - Alberta farm builds labour diversity into its core
[58]Source: RBC Though Leadership – Farmer 4.0
[59]Source: Canadian agri-food export opportunities in a COVID-19 world
[60]Source: Disruptive Technologies in the Agri-Food Sector

SWOT ANALYSIS — CCUS

STRENGTHS

Alberta is poised to establish itself as a leader in the growing CCUS movement in Canada, backed up by robust federal and provincial initiatives and regulatory frameworks (such as Carbon Capture and Storage Statutes Amendment Act and Carbon Sequestration Tenure Regulation)[61], as well as strong political support. The Alberta–Canada CCUS Steering Committee[62] and the 80 million (CAD) Industrial Energy Efficiency and Carbon Capture, Utilization and Storage Grant Program[63] are strong examples of federal and provincial initiatives to advance CCUS efforts in the province. Alberta is also at the forefront of the global CCUS discourse, with its involvement with China as a co-lead in the ISO committee for CCS standard development.[64]

Alberta's CCUS market is well-poised to support viable and profitable projects. On the supply side the province boasts unique geology,[65] world class large-scale CCUS infrastructure assets (such as the Alberta Carbon Trunk Line (ACTL)[66] as well as a long and proven track record in all technical aspects of CCUS.[67] On the demand side, Alberta has a high concentration of facilities around the Industrial Heartland and Fort McMurray that would provide a strong local market for CCUS technologies.[68] There is an emerging ecosystem of companies developing CO2-derived products within Alberta.[69]

The development of the CCUS industry in Alberta has been driven by top research institutions, industry partnerships, and technology accelerators, such as the CMC Research Institute, Alberta Innovates, Emissions Reductions Alberta (ERA), the Alberta Carbon Conversion Technology Centre (ACCTC), and the Canadian Oil Sands Innovation Alliance (COSIA). Unlike most parts of the world, the public support for land based CCUS has been largely positive.[70]

From an investment attraction perspective, it is worth noting that a number of recently announced major projects cited CCUS infrastructure as a key determinant in their decision to choose Alberta (e.g., Air Products H2, Dow net zero polyethylene and others),

WEAKNESSES

As the CCUS sector in Alberta continues to grow and evolve, it could be met with barriers that come with a weak regulatory framework. A lack of harmonized industrial codes and commodities standards for carbon-based products and capture technology will be a major impediment for mass deployment and adoption in the sector.[71] Thus, regulatory frameworks would need to be more robust and offer increased transparency to meet the needs of this potentially high-growth industry.

The industry is currently moving towards a hub-based infrastructure model, which can be cost-prohibitive, and energy-intensive, due to the need for large networks and transportation distances. It also limits employment opportunities around those CCUS clusters. A hybrid approach incorporating a distributive model can provide greater accessibility and emissions reduction opportunities.[72]

There's also room for more participation from potential customers, which includes any high-emitting company or industry. This is driven by the fact that many high-emitters (particularly those outside of the oil and gas sector) do not have an understanding of CCUS technologies and the associated benefits of adoption. This delayed adoption is slowing down the demand side of the market.[73] While companies such as Dow Chemicals are exemplifying the type of action needed through construction the world's first net zero carbon emissions petrochemical plant, more action and momentum is needed across industry.[74]

[61] Source: Government of Alberta - Carbon capture, utilization and storage – Overview
[62] Source: Canada and Alberta Launch Steering Committee to Advance CCUS
[63] Source: Government of Alberta - Carbon capture, utilization and storage – Overview
[64] Source: Canada Update: Select CCS Regulatory Developments
[65] Source: SWOT Interview
[66] Ibid.
[67] Source: Norton Rose Fulbright - Growing use of Carbon Capture, Utilization and Storage (CCUS) in Canada
[68] Source: SWOT Interview
[69] Source: The Carbontech Innovation System in Canada
[70] Source: SWOT Analysis Advisory Committee
[71] Source: The Carbontech Innovation System in Canada
[72] Source: Alberta CCUS Policy: An Interview with Tristan Goodman the President Of EPAC
[73] Source: The Delphi Group AIHA Study
[74] See: https://financialpost.com/commodities/energy/oil-gas/stagering-dow-plans-major-petrochemical-expansion-shift-to-net-zero-in-alberta

OPPORTUNITIES

Alberta's CCUS sector is heading into many exciting frontiers with opportunities to catapult it towards success. The voluntary carbon neutrality movement has prompted a growing interest in CCUS technologies in the industry. The Oil Sands Pathways to Net Zero Coalition is such an example of leadership commitments from major corporate emitters to achieve net zero targets using CCUS.[75]

Multiple pilot projects are currently in place, exploring new uses of sequestered carbon and the development of CO2 value-added products such as carbon nanotubes,[76] low carbon cement,[77] and carbon-to-fuels technologies. Large-scale demonstration projects, such as the major retrofitting project from Pembina Pipeline and TC Energy, also provides significant opportunity for Alberta to cement itself as a CCUS leader.[78] By 2030 the CCUS sector could employ over 1,700 people in Alberta and contribute more than $379 million in provincial GDP.

The 2021 federal budget has made commitments towards CCUS advancement, which can provide significant opportunities for the sector. These include, but are not limited to, a $319 million pledge for CCUS RD&D (research, development and deployment) efforts.[79] The government of Alberta's new competitive process for sub-surface rights will increase market efficiency in the CCUS sector.[80] Knowledge-sharing and demonstration opportunities in international export markets can also pave the way for an Alberta-led Canadian CCUS leadership.[81]

THREATS

Progress in the CCUS industry may be challenged in the future, as anti-CCUS ENGO campaigns[82] gain support and traction among the public and companies. Ultimately, such campaigns may generate low confidence and an unfavorable perception of CCUS. Educational and marketing efforts may help clarify misconceptions about CCUS technology amongst the general public. Some experts suggest that a CCUS tax credit may favor the status-quo of the oil and gas sector and undermine efforts to reduce fossil fuel subsidies. There are also concerns around the tax credit making other clean technologies appear relatively more expensive, which may lead to market distortion that favors greater emissions.[83]

[75] Source: Canadian Oilsands Heavyweights Commit to "Lead on Climate Change" in Net-Zero Plans Using CCUS
[76] Source: Carbon Upcycling Technologies
[77] Source: ERA - Lehigh cement Edmonton metropolitan region "CCUS feasibility studies"
[78] Source: Pembina and TC Energy Partner to Create World-Scale Carbon Transportation and Sequestration Solution: The Alberta Carbon Grid
[79] Source: Government of Canada – Budget 2021
[80] Source: Government of Alberta Carbon Sequestration Tenure Management
[81] Source: Carbon Capture, Utilization and Storage - Polarization, public confidence and decision-making
[82] Source: Carbon Capture, Utilization and Storage - Polarization, public confidence and decision-making
[83] Source: Canadian Institutes for Climate Choices - Policy Implementation Will Be Tricky on Carbon Capture and Storage

SWOT ANALYSIS — DIGITALIZATION

STRENGTHS

Alberta's digitalization space is characterized by its strong artificial intelligence (AI) and machine learning (ML) driven initiatives. The Edmonton Metropolitan Region and Calgary drive the economic activity of this sector through a unique synergy, as the former leads the research and innovation, while the latter supports entrepreneurial capacities.[84] Alberta is home to two of the global leaders in AI and ML research – the University of Alberta and the Alberta Machine Intelligence Institute (Amii).[85] Alberta's research recognition continues to attract foreign student enrollment in the STEM field,[86] which has positively affected the province's GDP. Alberta, particularly the Edmonton Region, is seeing the emergence of a strong local talent pool in AI, ML and other skillsets needed to drive digital technology development and implementation.

Federal funding support through the Pan-Canadian Artificial Intelligence Strategy, and AI Innovation Supercluster investment has been crucial to establishing Alberta's AI and ML expertise. The provincial government continues to prioritize this emerging sector through its earmarked funding for artificial intelligence research and investment attraction.[87] Alberta Innovates' Strategic Networking and Development Program[88] provides research and innovation support in other technology verticals, such as information and communications technologies (ICT).

The Edmonton Metropolitan Region – Alberta's AI and ML hub – has made a reputation for itself as an AI up-and-comer[89] and has attracted corporate investment from tech giants like Google, Amazon, IBM, and Microsoft. As early adopters of AI, Alberta has proven end-users like ATB Financial and Minestar Group, which demonstrate the growing use of digitalization services across sectors like financial services, healthcare, energy, agriculture, and advanced manufacturing.[90]

[84]Source: SWOT Analysis Advisory Committee
[85]Source: AI Funding in Canada & Major Research Cities
[86]Source: Pan-Canadian AI Strategy Impact Assessment Report
[87]Source: Boosting Competitiveness of Canadian Businesses: Clearing a Path to Widescale AI Adoption
[88]Source: Alberta Innovates - Strategic Networking and Development (SND) Grants
[89]Source: Opinion: Artificial intelligence could be Alberta's oilsands 2.0
[90]Source: Boosting Competitiveness of Canadian Businesses: Clearing a Path to Widescale AI Adoption
[91]Source: Opinion: Artificial intelligence could be Alberta's oilsands 2.0
[92]Source: It's Time We Talk: Bridging the Gap Between Business and AI
[93]Source: Alberta downsizing foreign worker programs, hoping to attract international biz and tech grads
[94]Ibid.
[95]Source: Boosting Competitiveness of Canadian Businesses: Clearing a Path to Widescale AI Adoption

WEAKNESSES

Alberta's digitalization space faces several labour force related barriers. Most of the workforce in the sector possess specialist-level knowledge of computer science and engineering. However, as application of digitalization services spread across diverse sectors, workers with a diverse set of integrative skills, such as business operations and social sciences, will be necessary for successful implementation.[91] In order for digital technologies to be more easily integrated across industries in Alberta, a more diverse workforce – with both digital knowledge domain and industry specific expertise – will be needed.

Alberta also faces an acute skilled labour shortage with a relatively low population, and AI graduates leaving the province[92] for better opportunities in other parts of Canada. The digitalization labour market is highly dependent on a skilled migrant workforce,[93] leaving it vulnerable to shifts in immigration policies. The University of Alberta's AI department has been facing challenges to meet the growing demand for graduate research programs, particularly for foreign students, as it faces scarcity of funding and faculty staffing.[94] This further limits the number of skilled migrant labourers that the province could potentially benefit from.

Businesses are facing challenges in integrating digitalization solutions in their systems. This comes from a gap in awareness among the leadership team or board members of the kinds of AI-driven business applications that are available. Lack of digital infrastructure also poses a barrier for wide-spread adoption.[95] Increased digital governance and capacity-building is required to transform organizations for the digital age.

OPPORTUNITIES

According to this study's analysis, by 2030 the digitalization sector could employ over 2,300 people in Alberta and contribute $540 million in provincial GDP. Digitalization will be a key feature across numerous economic sectors, including financial services, healthcare, energy, agriculture, and advanced manufacturing and will be a key driver to economic growth and employment in the coming decades. An estimate suggests that the demand for skilled tech workers is expected to grow twice as fast as overall employment by 2023.[96] Certain roles such as cybersecurity analysts, backend developers, UX/UI designers, which have cross-sectoral application will see more demand than others.[97] Alberta's leading industries, including energy, agriculture, and forestry, can be strong early adopters for locally developed digital technology.

Multiple collaborative and cohesive efforts are underway in the digitalization sector that could help bridge the fragmentation across the supply chain and provide capacity-building support for commercialization. There is potential to position the "Alberta Innovation Corridor" as a global digital innovation capacity leader and a support hub for SMEs developing digital tech.[98] A recent partnership between Attabotics, AltaML, and Alberta Machine Intelligence Institute, is a unique example of an industry and research collaboration that could lead to more integrated sector-wide efforts in the future.[99]

THREATS

Alberta is developing a one-sided digital narrative as it relates to AI and other pathways. The focus has been on academic and network capacity to-date and has not focused on commercialization and deployment, which is a key missing link for the sector.[100] The lack of collaboration between research institutes and industry further limits the full potential of Alberta's AI ecosystem.[101] The study's Advisory Committee also indicated that they feel that Alberta still leans heavily toward hard-tech development and capital project expenditures and that funding for software innovation remains relatively low in comparison.[102] Thus, holistic policy and funding mechanism, along with industry-wide collaborative partnerships, will be fundamental to advancing the digitalization sector.

The current policies (both at federal and provincial levels) are not well defined to include consideration for digital data management, cyber security, and data ownership.[103] As a result, a lack of clear policy and institutionalized frameworks related to cyber risk and privacy continue to hinder mass diffusion of many emerging digital technology pathways, such as machine learning, among businesses (e.g., Cancellation of Google's Sidewalk Labs Community in Ontario).

As AI and other technology verticals gain prominence, occupations such as auditors, financial analysts, and healthcare information management practitioners may face increasing risk of being displaced. Hence, a coordinated upskilling and reskilling strategy is required for these occupations to prepare and perform value-added work.[104]

In the global AI and ML landscape, Canada faces a comparative disadvantage against leading jurisdictions such as the U.S. and China. The efficiency of ML models depends on large database access to train on and improve. The U.S. and China have access to massive data sets to train their models, which gives them a leading edge against all global competitors.[105]

[96] Source: A Digital Future for Alberta
[97] Ibid.
[98] Source: Alberta Innovation Corridor
[99] Source: Attabotics Partners With AltaML and Amii to Bolster Artificial Intelligence and Machine Learning Capabilities for Supply Chains
[100] Source: SWOT Analysis Advisory Committee
[101] Source: SWOT Interview
[102] Source: SWOT Analysis Advisory Committee
[103] Source: Boosting Competitiveness of Canadian Businesses: Clearing a Path to Widescale AI Adoption
[104] Source: On the Edge of Tomorrow – Canada's AI Augmented Workforce
[105] Source: The race to the top among the world's leaders in artificial intelligence

SWOT ANALYSIS — ELECTRIFICATION

STRENGTHS

Alberta's electrification sector, characterized by its deregulated electricity market, has enabled public investors to participate and deploy their technologies. The competition in the market has allowed electricity prices to remain steady across the economy.[106] The EV market and associated infrastructure has been growing, supported by strong federal level funding[107] and vibrant community engagement.[108]

Municipal governments strategies (such as the active transportation strategies for both the Edmon-ton Metropolitan Region and Calgary)[109] and regional collaborations (such as the Peak-to Prairies Network)[110] are leading EV expansion efforts across the province. There has been significant progress across other electrification verticals. For instance, the University of Alberta and NAIT are leading research and demonstration in smart grid.[111] Despite being a medium-sized jurisdiction, municipalities in Alberta are punching above their weight in regard to the number of current and planned energy storage projects.[112]

WEAKNESSES

Alberta's electricity grid is carbon intensive, limiting its potential to achieve net zero targets.[113] Thus, the share of renewable energy in Alberta's grid must improve significantly. The province is lagging in terms of residential, commercial, and industrial policies requiring a shift to electrified equipment compared to other jurisdictions, such as Ontario, which requires new furnaces in residential homes to be non-emitting by 2031.[114] There is a fragmentation of policy and funding initiatives among the municipalities and the province for progressing the electric vehicle market. Considerable policy and funding efforts exists at the municipal level, while the province has no clear directive – creating uncertainty among investors.

The EV market faces numerous challenges as it grows and evolves. Alberta does not have any provincial government incentives or quotas to encourage the move to EVs or plug-in hybrids (PHEVs) compared to other provinces such as Quebec, which offers up to $8,000 in rebates.[115] Equipment and installation costs of charging stations, especially the retrofitting cost for home charging, pose significant barriers in the market.[116] Lack of accurate information on EV ownership, due to voluntary purchase disclosure, limits policy and infrastructure decisions.[117] The mass adoption of EV is also hindered by unfavorable public perception of EV ownership.[118]

OPPORTUNITIES

Alberta's electrification efforts are currently focused on grid modernization and electric vehicles. However, there is a significant opportunity for Alberta to electrify and reduce emissions from heavy industry processes. Development of game-changing electrification technologies such as radio frequency heating for bitumen extraction can support the province in achieving this goal. By 2030 the electrification sector could employ 3,000 people in Alberta and contribute more than $526 Million in provincial GDP.

Excellent renewable energy resources, specifically wind and solar, can support decarbonization as deployment increases over the next decade. Alberta's energy transition can provide a pathway to integrate energy equity and energy resilience strategies, ensuring a just distribution of energy across communities.

THREATS

The absence of a provincial roadmap for grid decarbonization creates some uncertainty on how low-carbon technology may be deployed in the electricity sector. Thus, a strategy incorporating electrification into a comprehensive climate, transportation, and infrastructure plan could support achieving net zero targets in the sector.

The EV market may face numerous uncertainties in the future. As usage of EVs goes up, uncontrolled and simultaneous charging could significantly increase congestion in power systems and peak load.[119] The province may need to look for alternative funding for EV infrastructure, since the infrastructure funding received from provincial and federal fuel taxes will decline because of decarbonization goals.[120]

Changes to fuel consumption regulations in the United States may slow down the development of fully electric pickup trucks and SUVs[121] (potentially tempered by the recently elected Biden government). This could significantly affect EV adoption in Alberta, as light-duty vehicles – particularly SUVs – are the most widely used vehicle type in the province.[122]

[106] Source: SWOT Interview
[107] Source: Government of Canada- Zero Emission Vehicle Infrastructure Program
[108] Source: Electric Vehicle Association of Alberta - Community Engagement
[109] Source: Electric Vehicle Home and Workplace Charging Study
[110] Source: Peak to Prairies
[111] Source: SWOT Interview
[112] Source: SWOT Analysis Advisory Committee
[113] Source: SWOT Interview
[114] Source: Goodbye, gas furnaces? Why electrification is the future of home heating
[115] Source: Want to buy an EV? Slow down there, we're in Alberta
[116] Source: Electric Vehicle Home and Workplace Charging Study
[117] Source: Want to buy an EV? Slow down there, we're in Alberta
[118] Ibid.
[119] Source: Utilities tackling supply challenges, smart charging opportunities in EV-led disruption
[120] Source: Future of Transportation in Calgary Study
[121] Ibid.
[122] Source: [1] Wheels of change: Pickup trucks no longer Alberta's favourite vehicle | Globalnews.ca

SWOT ANALYSIS — ENERGY EFFICIENCY

STRENGTHS

Alberta's strength in the energy efficiency sector is driven by its well-established cogeneration and HVAC industry. With some of the largest facilities[123] in Canada, and a well-established infrastructure,[124] the cogeneration sector boasts over 20 years of proven track record of supporting Alberta's electricity system.[125] The surplus of energy has helped the electricity grid to continue to be reliable and low cost.[126] Cogeneration has a 50 percent capital allowance rate in Canada, which allows it to operate at a lower cost compared to other waste heat recovery technologies.[127] Alberta also has the most competitive HVAC market among the provinces.[128]

Alberta is one of the four provinces to adopt Property Assessed Clean Energy style program to facilitate financing of energy efficient improvements in buildings through property tax. This legislation enables municipalities to access federal support to develop their efficiency plans under the Federation of Canadian Municipalities' Community Efficiency Financing (CEF) initiative.

WEAKNESSES

Alberta lags other jurisdictions in terms of energy efficiency policies and initiatives and has been performing worse in recent years – in the Canadian Energy Efficiency Policy Scorecard for 2020, the province fell to eighth position, a significant drop from its position as sixth last year.[129] Currently, there are no formal energy saving targets or any commitment to move towards net zero energy buildings in Alberta. Compared to the rest of Canada, the province has the lowest petajoules of electricity saved from energy efficiency initiatives as a proportion of overall domestic sales of electricity.[130] Alberta is also far behind in building code requirements which impedes uptake of energy efficient technologies and building techniques.[131]

Cogeneration, the largest economic activity in Alberta's energy efficiency sector, emits GHGs and incurs a carbon tax for non-industrial applications under current policies. Cogeneration production is largely oil-sands based, with lack of standardization across the industry.[132] Thus, over reliance on cogeneration will make it difficult to achieve a net zero pathway.

Trades are highly regulated by Alberta government, and schools like NAIT and SAIT cannot modify trade curriculum at this time to include more clean energy related topics. This limits the knowledge on different energy efficiency verticals and pathways among the workforces.[133]

OPPORTUNITIES

The growth of the cleantech sector shows potential to advance energy efficiency performance, as energy efficiency technologies can be implemented across various sectors and industrial users. There are significant opportunities to expand industrial process energy efficiency and low carbon heat recovery efforts in the province.[134] Alberta has developed expertise in large-scale waste heat recovery, which may offer considerable export opportunities to regions looking to develop similar projects. By 2030 the energy efficiency sector could employ over 9,500 people in Alberta and contribute $1.4 billion in provincial GDP.

Municipal-led initiatives show potential to improve energy efficiency technology uptake, particularly at the residential or MURB (multi-unit residential buildings) level. The Edmonton Metropolitan Region's Building Energy Retrofit Accelerator will support efficiency upgrades to commercial and institutional buildings,[135] while the Clean Energy Improvement Program could be extended at commercial and industrial scale.[136] On September 7, 2021, the City of Calgary passed 'The Clean Energy Improvement Tax Bylaw'. The bylaw will establish the Clean Energy Improvement Program (CEIP) in Calgary and authorize the City to borrow up to $15 million for financing clean energy improvements on eligible properties.[137] There remains a strong opportunity for both Calgary and municipalities within the Edmonton region to build on actions such as the bylaw to take a leadership role in the development and deployment of energy efficiency technologies. Stakeholders also indicated that there is an opportunity to improve the perception around energy efficiency programming by prioritizing rebates and incentives for low-income families and individuals who need extra support upgrading their homes.[138]

THREATS

Energy efficiency initiatives in Alberta have a long history of fluctuations with change in government, as political interests in energy efficiency have shifted.[139] A low degree of support for efficiency through frequent defunding or decisions to scrap programs has led to persisting uncertainty around energy efficiency. The recent cancellation of the provincial carbon levy and the ensuing closure of Energy Efficiency Alberta,[140] has sent mixed signals to technology developers and investors in this space.

Beyond inconsistent policy and government support for energy efficiency, the largest threats to in-creased activity in this sector are the lack of standards and regulations to spur activity.

[123] Source: Market Snapshot: Alberta cogeneration capacity has grown significantly in the last 15 years, led by oil sands projects
[124] Ibid.
[125] Source: Suncor building $1.4B cogeneration units in Alberta oilsands
[126] Ibid.
[127] Source: Income Tax Folio S3-F8-C2, Tax Incentives for Clean Energy Equipment
[128] Source: 2020 Canadian Plumbing & HVAC Industry Competitive Analysis by Province
[129] Source: Canadian Energy Efficiency Policy Scorecard – Alberta
[130] Source: 2020 Provincial Energy Efficiency Scorecard - Efficiency Canada
[131] Source: SWOT interview
[132] Source: A Review of Cogeneration in Alberta
[133] Source: SWOT Interview
[134] Ibid
[135] Source: City of Edmonton metropolitan region - Building Energy Retrofit Accelerator
[136] Source: SWOT Interview
[137] See: Clean Energy Improvement Program Bylaw (escribemeetings.com)
[138] Source: SWOT Analysis Advisory Committee
[139] Source: Unpacking the Climate Potential of Energy Efficiency
[140] Source: 2020 Provincial Energy Efficiency Scorecard - Efficiency Canada

SWOT ANALYSIS — HYDROGEN

STRENGTHS

Alberta has positioned itself as a leader in Canada's hydrogen economy, as it is the largest producer and consumer of hydrogen in Canada due to its strong petrochemical cluster. Looking forward, the established CCUS ecosystem will be crucial to the production of blue hydrogen in order to reduce the carbon intensity of the industries with high energy requirements, as well as supply new hydrogen markets. Thus, many of the strengths of the provinces' hydrogen economy are dependent on the CCUS and energy sectors; these include unique geology for CCUS,[141] well-established hydrogen transportation infrastructure,[142] and expertise in the manufacture and use of auxiliary equipment.[143] Supported by robust federal[144] and provincial[145] level strategies. Recently, Alberta's Industrial Heartland Hydrogen Task Force led the charge to establish Canada's first hydrogen hub[146] in the Edmonton Metropolitan Region, which is helping to accelerate and grow supply and demand of hydrogen in Alberta.

WEAKNESSES

Despite its strong potential, the hydrogen market in Alberta faces market related barriers that limit its progress in the energy transition. Currently there is limited use of green hydrogen, given the geographical separation of renewable assets from many hydrogen assets.[147] The feasibility of hydrogen as a technology pathway is constrained by its higher cost compared to natural gas and other generation sources.[148] The manufacture of hydrogen-based goods is limited in the region, as there are no existing facilities for vehicle and consumer goods (e.g., household hydrogen furnaces) production.[149] The demand for hydrogen is also yet to expand beyond the industrial sector.[150] Thus, a comprehensive and cohesive policy on the overall hydrogen economy and associated goals will be necessary, at both the provincial and federal level, to advance the sector.[151]

OPPORTUNITIES

The use of hydrogen can help achieve net zero targets by replacing carbon-based fuels in high emitting sectors. The Edmonton Metropolitan Region's transportation corridor and heavy industry hub could present an opportunity for local market uptake. As carbon intensity of blue hydrogen is tied to upstream emissions of natural gas production, the hydrogen economy provides a pathway for decarbonizing natural gas when combined with CCS.[152]

Alberta's hydrogen economy is progressing in its pathway to commercialization, with demonstration projects like a hydrogen blending project in Fort Saskatchewan,[153] and development of two large scale industrial hydrogen projects (including Air Products)[154] underway. The Southeast Alberta Hydrogen Task[155] force was recently formed to establish Canada's second industrial hydrogen hub. As demand for hydrogen grows exponentially worldwide,[156] Alberta will have the opportunity to leverage its growing infrastructure and strong technical capabilities in the global hydrogen market. The province could tap into the growing overseas market in Japan, and South Korea, which have limited domestic production potential.[157] By 2030 the hydrogen sector could employ more than 1,000 people in Alberta and contribute $403 million in provincial GDP.

In addition to hydrogen production, there is significant potential in transportation technologies and material development. The $9.2-million Alberta Zero Emissions Truck Electrification Collaboration (AZETEC) project will be an important proof point for hydrogen deployment in the trucking sector.[158] Hydrogen-derived products, such as methanol and/or ammonia, could provide further opportunities to increase the value of existing hydrogen infrastructure and resources.[159] Already there have been strong signals from multinational enterprises (MNEs) like Petronas, Itochu, Mitsubishi, Shell and others that they are exploring investing in the emerging hydrogen economy in Alberta.

THREATS

As Alberta's hydrogen sector matures, there may be significant supply-side barriers associated with regulatory frameworks. This may include lengthy regulatory review and approval processes for infrastructure construction or lack of interjurisdictional cooperation to establish certification protocols.[160] Technical hurdles around retrofitting existing pipelines and finding chemical carriers may also limit supply of hydrogen.[161]

The demand of blue hydrogen may be dampened with future cost reductions in green hydrogen production.[162] The blending of hydrogen without subsidies may lead to a higher cost of living over the short-to-medium term for residential consumers, which may also significantly affect the demand.[163] The prevailing ENGO narrative on blue-hydrogen as a "trojan horse of the oil and gas economy" may negatively skew public perception.[164]

In the global hydrogen landscape, other markets have begun to move in this space as Australia and Saudi Arabia have already sold hydrogen to buyers in Japan.[165] To remain competitive, Alberta must develop a comprehensive hydrogen export strategy.

[141] Source: Building A Transition Pathway to A Vibrant Hydrogen Economy in The Alberta Industrial Heartland
[142] Source: Government of Alberta - Natural Gas Vision and Strategy
[143] Source: The Delphi Group AIHA Study.
[144] Source: Hydrogen Strategy for Canada
[145] Source: Government of Alberta - Natural Gas Vision and Strategy
[146] See: https://erh2.ca/
[147] Source: The Delphi Group AIHA Study
[148] Source: Building an Albertan Hydrogen Economy
[149] Source: The Delphi Group AIHA Study
[150] Source: SWOT Analysis Advisory Committee
[151] Ibid.
[152] Source: SWOT Analysis Advisory Committee
[153] Source: Suncor and ATCO partner on a potential world-scale clean hydrogen project in Alberta
[154] Source: Air Products Announces Multi-Billion Dollar Net-Zero Hydrogen Energy Complex in Edmonton metropolitan re-gion , Alberta, Canada
[155] Source: Task Force established to Advance Hydrogen Economy in Southeast Alberta
[156] Source: Hydrogen scaling up
[157] Source: Building A Transition Pathway to A Vibrant Hydrogen Economy In The Alberta Industrial Heartland
[158] Source: Emission Reduction Alberta - Alberta Zero-Emissions Truck Electrification Collaboration
[159] Source: The Delphi Group – AIHA Study
[160] Source: Alberta's hydrogen strategy – economic boon or blimp?
[161] Source: The Delphi Group AIHA Study
[162] Source: Green Hydrogen, The Fuel Of The Future, Set For 50-Fold Expansion
[163] Source: The Bold and The Blue-tiful: Canadian Oil and Gas' Role in the Hydrogen Economy
[164] Source: SWOT Analysis Advisory Committee
[165] Source: A $100B opportunity: Alberta could emerge as Canada's first hydrogen energy hub, report says

FUTURE MARKET GROWTH & TRENDS

2.1 Sub-sector Macro Trends and Alberta Innovation Ecosystem Benchmarking

Achieving a comprehensive energy transition that not only reduces emissions but facilitates and accelerates economic growth requires pursuing areas of opportunity for Albertan companies to launch and export technologies that underpin an energy transition. A critical challenge for governments seeking to lead in technology innovation is resisting the temptation to attempt picking local winners, and instead develop a comprehensive innovation ecosystem that fosters innovation and perpetual advantage in technology development. Building innovation clusters (research, demonstration, supply chain, manufacturing, commercial deployment) around constituent technologies associated with energy transition will yield positive decarbonization benefits for Alberta, but also contribute to offsetting economic trade-offs associated with the energy transition, i.e., carving out places for new local industries as the province's energy supply shifts away from oil and gas.

To assess Alberta's ability to participate in and lead technology development within the subsectors for energy transitions, the project team took a demand-first approach to understand which energy transition technologies are the focus of demand-pull. These demand-pull technologies were then compared against the ability of Alberta's innovation ecosystem to launch and export technologies, versus global competitive ecosystems.

KEY FINDINGS: HYDROGEN PRODUCTION & UTILIZATION

This analysis reviewed global potential for uptake of hydrogen production technology, with a focus on the areas of existing capabilities in Alberta, such as blue hydrogen (hydrogen from natural gas, but still below a specific CO2 emissions threshold).

Hydrogen will be a critical means for reducing emissions across many industries' emissions profiles, especially as part of a net zero strategy. The market for hydrogen, globally, is significant, currently estimated at just below $200 billion and expected to grow to $420 billion by 2030 and reach $2.5 trillion by 2050.[166] Investors and corporations globally have demonstrated an eagerness to participate in financing of low-carbon hydrogen (grey and blue hydrogen) production technologies, with venture capital firms having invested over $400 million into low-carbon hydrogen production technologies since 2016.

> *Within the low-carbon hydrogen market, Alberta is positioned as a potentially competitive ecosystem, with the continued deployment of large-scale projects and emergence of early-stage innovators.*
>
> *Becoming a technology contender in hydrogen production will require Alberta to go beyond attracting and promoting large projects; it will require investment in an ecosystem that launches successful innovation*

However, producing hydrogen from non-renewable sources presents challenges in the ability of current infrastructure to prevent methane leakage from natural gas assets. It also requires use of highly efficient carbon capture technologies to ensure that a threshold of 2.256 tCO2eq/tH2 (the threshold put forward by in the 2021 Renewable Hydrogen Coalition letter to EU Commission) can be met. As a result, there is potential for enthusiasm around low-carbon hydrogen production technology to reach a plateau globally, despite the growing need for hydrogen as a chemical.

Within the low-carbon hydrogen market, Alberta is positioned as a potentially competitive ecosystem, with the continued deployment of large-scale projects (such as the aforementioned $1.3 billion Air Products facility and a forthcoming 11,000 tpa Suncor and ATCO production facility) and emergence of early-stage innovators. Proton Technologies is an example of an early-stage innovator demonstrating the ability to bridge the R&D-to-commercial gap, already licensing technology to Whitecap Resources for production of hydrogen at 500 tons per day.

Becoming a technology contender in hydrogen production will require Alberta to go beyond attracting and promoting large projects; it will require investment in an ecosystem that launches successful innovation. Albertan hydrogen innovators received less than $2 million in venture investments 2011 to 2021, versus nearly $1.75 billion and $325 million in California Bay Area and Northern England innovators, respectively. A focus on applied research and comprehensive technology transfer to industry will not only launch innovators into a fertile demonstration market, but likely be an attractive selling point to multinationals considering subsidiary locations.

[166] Source: EY Hydrogen Future POV_2021-10-22.pdf(Review)- Adobe Document Cloud

KEY FINDINGS: AG-TECH & AGRICULTURE

The market for agriculture is highly fragmented, with a wide array of technologies and chemicals used on farms, in livestock operations, in agricultural product manufacturing, and monitoring of each production phase. In this analysis, agricultural technology directly relevant to an energy transition was the focus and was segmented into three buckets: agricultural efficiency (including robotics, monitoring and automation, and electrification of equipment), crop biosciences (including engineered crops and sustainable crop treatments), and alternative proteins (proteins from non-animal sources: from crops or lab-engineered materials).

The global markets for agricultural efficiency technology are still highly fragmented by application area but are beginning to move toward consolidation – many hardware technologies focus on one function but are being unified and coordinated through improvements in connectivity and software. The crop biosciences market presents the challenge of requiring large-scale operations to take early-stage ventures into global markets, requiring significantly more capital than more scalable software or even electronics technologies.

Both markets remain relatively small; agricultural efficiency slated to grow to $10.8 billion by 2023, and crop biosciences to just under $2 billion by 2025. Alberta boasts a rich agricultural ecosystem as well as an advantage of proximity to export markets, including the United States and Asia. Despite the strong potential for export of agricultural end-products, Alberta lags behind competitive regions with regards to ability to launch and sustain innovation. While the province has some emerging innovators such as Trustbix, G2V or Future Fields have all recently raised multi-million-dollar investments. Verge (agricultural software) and Decisive Farming (crop biosciences), there is significantly less financing volume to innovators than peer ecosystems. Further leveraging of a strong constellation of university and government-funded research into areas such as crop biotechnology (University of Alberta and University of Lethbridge) and more intentional efforts to fund pilot testing of emerging technologies can improve the ability of Albertan technologies to move into export markets.

Perhaps the most noteworthy development in agricultural technology in recent years has been the advent of alternative proteins, which are expected to comprise 10 percent of global protein market share by 2029 for a $140 billion market size. Alberta has unique resources allowing it to potentially participate in this market, namely, an abundance of land, access to water, availability of key feed-stocks (peas and beans), and established research programs in food science and bioscience in local universities.

More importantly, Alberta has home-grown success stories – Nabati Foods is a globally-distributed brand of plant-based foods with established channels through Walmart, Costco and Amazon, along with 600 points of sale in North America. Alternative protein growth medium play, Future Fields, recently graduated from the Bay Area Y Combinator Accelerator. Moreover, momentum is building to position Alberta as a subsidiary destination for global incumbents – in 2021 U.K. alternative protein company Meatless Farm announced a large-scale production facility to be opened in Alberta.

Capitalizing on this momentum, and Alberta's natural advantages, necessitates intentional efforts to transfer technology into the commercial market and attract more financing to local innovators – the biggest disadvantage that Alberta faces in alternative proteins is that competing supplier ecosystems are launching tomorrow's global incumbents (e.g., $2.4 billion of venture investment into California Bay Area companies that birthed Impossible Foods and Beyond). A critical component of the Bay Area ecosystem is highly focused R&D efforts at local universities to launch dedicated alternative protein research labs that collaborate with multinational corporations (e.g., the California Berkeley Alternative Meats X-Lab). This is the type of effort that Alberta likely can replicate at the earliest stages of innovation to ensure that R&D is demand-oriented and attracts investor attention early on.

Another key area of growth for Alberta is in agricultural carbon abatement. Alberta has transacted over 16 mega-tonnes (Mt) of on-farm offset credits. As a result, aggregators and producers have developed considerable expertise in this area. Telus Ventures recently invested in Radicle Group,[167] a carbon abatement project developer based in Alberta which has transacted over 6 Mt of carbon. In parallel to the growth of CCUS technology demand, the call for nature-based carbon abatement solutions and decarbonization options in the agriculture value chain, which accounts for roughly 17 percent of global emissions, will grow.

> *Alberta boasts a rich agricultural ecosystem as well as an advantage of proximity to export markets, coupled with a strong constellation of university and government-funded research into areas such as crop biotechnology.*
>
> *A key area of growth for Alberta is in agricultural carbon abatement. Alberta has transacted over 16 mega-tonnes (Mt) of on-farm offset credits. As a result, aggregators and producers have developed considerable expertise in this area.*
>
> *Capitalizing on this momentum, and Alberta's natural advantages, necessitates intentional efforts to transfer technology into the commercial market and attract more financing to local innovators.*

[167] Source: Radicle Announces Investment by TELUS Ventures to Accelerate Growth | Radicle (radiclebalance.com)

KEY FINDINGS: ENERGY EFFICIENCY

During the shift to alternative energy sources and fuels, achieving net zero requires that operators of facilities, and especially industrial operations, optimize energy and heat usage at every operational turn. The global market for waste heat recovery and reuse alone is estimated at $50 billion, and the market for energy efficiency in buildings is already over $100 billion.

> *Alberta has some existing advantages in digital technologies for energy efficiency, rooted in local innovation and deployment of digital oilfield technologies, which received $44 million in investment over the past decade*
>
> *The abundance of industrial operations in Alberta creates a potentially vibrant opportunity zone for corporate incumbents to test energy efficiency and waste heat recovery technologies. It also presents an opportunity for innovators of these technologies to secure critical pilot testing and demonstration platforms.*

The dropping price of sensors and improved accessibility of artificial intelligence technology has instigated an acceleration of capabilities to not only monitor but automate control of buildings and on-site energy assets. Smart equipment, energy-savings-as-a-service, and next-generation building information modeling technology companies are recording record numbers of investment – at time of writing, more financing went toward energy efficiency innovators in the first three quarters of 2021 than in all of 2019 and 2020. Waste heat recovery, too, is on an upward trajectory of industrial uptake, as technologies mature and corporations come under more pressure to reduce emissions and record more efficiency in operations – waste heat technologies such as electro turbo compounding can reduce CO2 emissions of existing systems by 15 percent or generate 10 percent more power.

The abundance of industrial operations in Alberta creates a potentially vibrant opportunity zone for corporate incumbents to test energy efficiency and waste heat recovery technologies. It also presents an opportunity for innovators of these technologies to secure critical pilot testing and demonstration platforms. Alberta has some existing advantages in digital technologies for energy efficiency, rooted in local innovation and deployment of digital oilfield technologies, which received $44 million in investment over the past decade. While Albertan technologies in this field have indeed received market traction, e.g., Hifi with GE, Shell, and Suncor, Alberta accounts for only one percent of digital oilfield venture investments globally in that same period. Similarly, while there has been enough venture financing to keep the energy efficiency sector healthy in Alberta (total $182.4 million since 2011), the ecosystem is significantly outpaced by other innovation hubs such as the Bay Area ($7.3 billion) and Munich ($1.42 billion).

> *Collectively, Alberta's waste heat recovery innovators have raised just over $81 million since 2011, more than innovators in competing ecosystems such as Sweden ($59 million in the same period) and the United Kingdom ($68.8 million).*
>
> *Waste heat recovery, especially, presents a unique opportunity for Alberta to position itself as the premier global innovation ecosystem, and continue momentum in launching differentiated waste heat recovery innovation, with University of Calgary graduates founding established waste heat recovery companies such as Genalta Power and Kanin Energy.*

Waste heat recovery, especially, presents a unique opportunity for Alberta to position itself as the premier global innovation ecosystem. Large corporate projects such as Siemens' and TC Energy's forthcoming waste-heat-to-power facility (announced in 2021) to power 10,000 homes, alongside NuVista's four waste heat recovery units across Grande Prairie are all tangible pipelines creating demand of local innovators. Alberta has momentum in launching differentiated waste heat recovery innovation, with University of Calgary graduates founding established waste heat recovery companies such as Genalta Power and Kanin Energy.

Collectively, Alberta's waste heat recovery innovators have raised just over $81 million since 2011, more than innovators in competing ecosystems such as Sweden ($59 million in the same period) and the United Kingdom ($68.8 million). While these are assets in achieving local net zero goals, the vulnerability for global technology competitiveness is a regional emphasis on project development versus differentiated technology development (e.g., Kanin Energy, differentiated by know-how, as opposed to Genalta who holds patents). Capturing and maintaining a leadership position in waste heat recovery will require Alberta's R&D, investment, and corporate players to place a priority on developing and piloting unique technologies to reduce economic trade-offs associated with energy transition.

KEY FINDINGS: CARBON CAPTURE, USE, STORAGE (CCUS)

CCUS technologies, capturing CO2 from fuel combustion or industrial processes and using it as a feedstock or sequestering it long-term, are critical both to reducing industrial emissions and creating bridge processes that reduce fossil fuel emissions during the eventual shift to renewables. The International Energy Agency (IEA) names CCUS as one of the four "key pillars" of global energy transitions and the market is estimated to reach $3.5 billion by 2025.

Alberta's greatest advantages in developing a competitive CCUS innovation ecosystem comes from access to large-scale industrial processes, which offer collaborative opportunities for innovators to pilot technologies and for incumbents to invest further in subsidiary operations to access knowledge. Global incumbents such as Lafarge Holcim are engaging the ecosystem through col-laboration with Carbon Upcycling and acceleration of Carbonova. The relative abundance of corporate players and projects makes Alberta one of the best venues for innovators to connect to demand.

Where Alberta loses ground versus competitive ecosystems is the launch of innovative companies out of local universities and the subsequent financing post-commercialization. As a comparison, universities in California and the U.K. have been able to launch spinouts or incubate companies that went on to compete in commercialization, such as Twelve at Cyclotron Road (Cal. Berkeley) and Econic Technologies, which spun out of Imperial College London and received early financing from Imperial Innovations. California and U.K. innovators benefit greatly from the presence of corporates and large-scale projects in the ecosystem through significant fundraising rounds supported by industrial incumbents such as Chevron, BP, and OGCI. California CCUS innovators saw $723 million in investment 2011 to 2021, and U.K. innovators $279 million in the same period. Given Alberta's strength in large projects, which will accelerate need for CCUS through continued hydrogen growth, and active corporate collaboration with innovators, it is likely that similar financing could emerge in Alberta to support CCUS innovators through the growth continuum.

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KEY FINDINGS: GEOTHERMAL

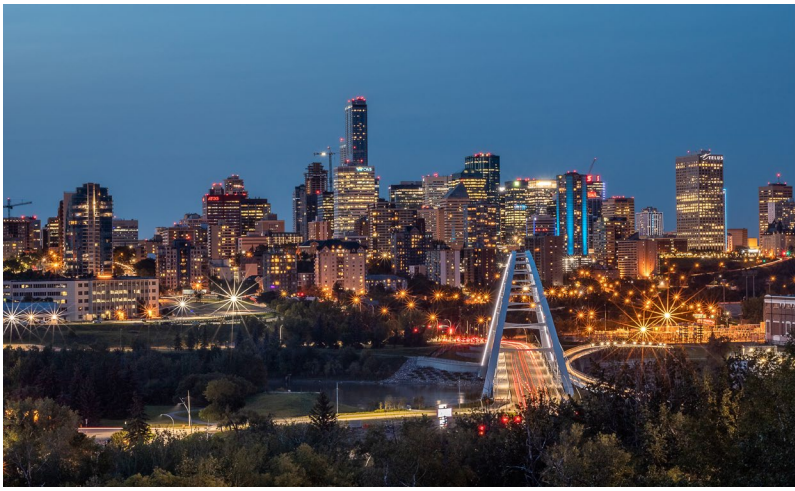
Though scale is constrained by geography, geothermal energy is being increasingly considered by corporations and local governments as a viable means in achieving local net zero goals. Alberta has a unique potential to tap into the geothermal market due to its natural heat reserves and the existing oil and gas knowledge base, which creates a critical pool of talent for drilling and equipment handling in geothermal operations. Despite a relatively small market for geothermal (estimated to be just over $5 billion by 2026), novel and cost-effective techniques for accessing power-enabling heat zones will have export markets especially in emerging economies.

> *Alberta has a unique potential to tap into the geothermal market due to its natural heat reserves and the existing oil and gas knowledge base; with access to a critical knowledge base in subsurface monitoring and drilling, two highly specialized disciplines that carry over directly to geothermal.*
>
> *This expertise, coupled with the presence of oil and gas incumbents with geothermal experience such as Enbridge, provides a critical connection-to-demand advantage.*

Alberta has traditionally not focused on geothermal energy due to the abundance of other energy sources. However, the province has at its disposal a critical knowledge base in subsurface monitoring and drilling, two highly specialized disciplines that carry over directly to geothermal. Additionally, geothermal energy in recent years has been accelerated by the transfer of technologies from fracking, which has reduced cost – Alberta has talent pools that will be immediately familiar with these technologies.

Indeed, Alberta has already seen success in launching proficient innovators. Calgary-headquartered Eavor Technologies has developed a proprietary closed-loop geothermal power generation system with live demonstration projects with Shell in Alberta, as well as a planned project with Enex in Germany set to kick off in 2022. Eavor has secured over $63 million from investors including Ever-source Capital, Chevron, BP Ventures, and BDC. Edmonton-based Terrapin is another example of an innovative geothermal technology.

The presence of oil and gas incumbents with geothermal experience, such as Enbridge, provides a critical connection-to-demand advantage. Geothermal innovation clusters have emerged in Iceland (with HS Orka leading) and Sweden (Baseload Capital, Climeon), but there is no de facto global innovation hub, leaving a potential leadership position for Alberta to fill.



KEY FINDINGS: GRID DIGITALIZATION

Shifting to a more efficient, cleaner grid, involves the use of comprehensive grid monitoring, command and control, and cyber security tools for optimized operations and resilience. The decreasing cost of computing power, sensors, and a rapid pace of innovation in communications technology has made grid digitalization more accessible than ever, despite the highly regulated and fragmented markets globally. Although there is an existing provincial knowledge base in pipeline and oilfield digitalization, Alberta's innovation ecosystem has not seen a multitude of innovation in the wider grid digitalization spaces. This creates a future challenge as more economies globally shift away from fossil fuel-based energy systems.

> *Opening up more opportunities for testing and procurement of grid digitalization can potentially be a means of leveraging the emerging research environment in Alberta to keep R&D demand-focused and develop experience for innovators at home that will be transferable abroad.*

Calgary-based home energy storage company Eguana has succeeded in offering consumer-facing home batteries that potentially allow users to participate in virtual power plants. More potential innovation can emerge out of research initiatives such as the Alberta Machine Intelligence Institute, the University of Alberta Energy Digitalization Lab, and University of Calgary System and Controls Group.

An area of grid digitalization where Alberta may have a head start is that of digital twinning –Edmonton-based innovators RUNWITHIT Synthetics has collaborated with AT&T, while Calgary-based Veerum counts GE and Cenovus among its customers. In February 2021, the Alberta Utilities Commission released a report naming digitalization as an increasingly relevant trend. Opening up more opportunities for testing and procurement of grid digitalization can potentially be a means of leveraging the emerging research environment in Alberta to keep R&D demand-focused and develop experience for innovators at home that will be transferable abroad.

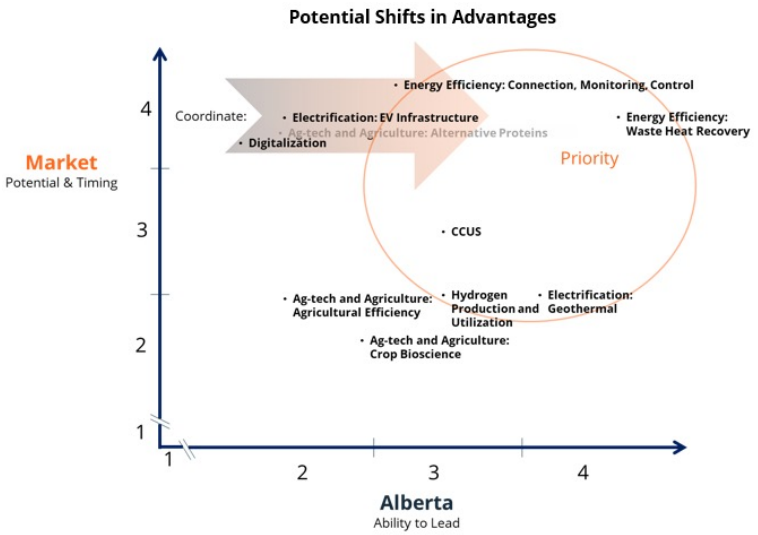
KEY FINDINGS: ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Despite a slow start, the market for electric vehicle (EV) charging infrastructure is set to expand precipitously through this decade to a market size of $150 billion by 2030. As EVs become more affordable and uptake by consumer, commercial, and industrial buyers continue to expand, rolling out a comprehensive charging infrastructure will become a challenge area for many geographies globally.

In Alberta, an electric vehicle charging network must be developed over long distances, a challenge that is already being addressed in part by programs such as Peaks to Prairies and the Electric Vehicle Universal Fast Charge corridor. While EV charging networks are being rolled out incrementally in Alberta, local innovation does not seem to be keeping pace. Despite some research activity at the University of Calgary and initiatives through the Transitions Accelerator, there are few local innovators with commercialized technology. This will be a challenge to developing innovation that meets demand-owner needs in coming years, as investors and corporate incumbents are already looking to Silicon Valley and multiple regions in China for innovators to engage and to deploy demonstration projects.

KEY FINDINGS: ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Alberta has local advantages that can already be leveraged for near-term wins in areas such as waste heat recovery, geothermal, and CCUS. However, other areas covered in this analysis, namely energy efficiency for buildings, grid digitalization, and electric vehicle charging, all have overlap in large-scale corporate players and investors. Coordinated efforts to develop an Alberta value chain around these technologies, e.g., focus on developing and deploying the technologies that solve Alberta's unique challenges first, is a strategy to arrive at a portfolio of technologies that can eventually be exported to other similar economies. See the proposed prioritization grid below for more detail.



More specific recommendations for Alberta's innovation ecosystem include:

- Capitalizing on waste heat recovery technology development in high-heat industries is a key opportunity for Alberta. Developing a value chain of underlying components, multi-application products, and innovative service models will improve exportability. As an example, multiple sites in Alberta have piloted next- generation waste heat recovery technology at pipeline compression sites, including the 2021-announced Siemens and TransCanada project to feed energy (enough to power 10,000 homes and offset 44,000 T CO2e per year) from recovered waste heat at a pipeline compression site into a local grid, and a NuVista deployment at various compression sites that will offset 4,500 T CO2e per year.
- Geothermal represents an opportunity to develop local alternative energy sources, leverage existing local infrastructure and workforce capabilities, and develop exportable suites of technologies for global geothermal markets. In addition to significant momentum in geothermal demonstration projects (Eavor Loop, Alberta No. 1 in Grande Prairie, Razor Energy in Swan Hills), Alberta has a highly skilled workforce capable of leveraging drilling knowledge and expertise to access geothermal potential in new reserves and inactive oil and gas wells.
- Energy efficiency, digitalization, and electrification can be developed in parallel – many of the benefits of each sector spill over into each other. Forming value chains around industrial electrification / efficiency in heavy industry will be a way to leverage multiple trends for growth.
- A targeted effort to upgrade the grid along with cutting-edge tech implemented at the nodes of buildings and EV charging can push Alberta into a more competitive position.
- CCUS will be key to the decarbonization of Alberta's energy system and industries. The availability of companies and assets makes Alberta an ideal technology piloting venue, brings in external innovators to pilot and test, raising the competitive bar for local innovators. Develop exportable tech advantages.

3.1 Value Proposition Statements

Unique value propositions for Alberta, Calgary and the Edmonton Metropolitan Region were developed to highlight the key strengths and differentiators of each region as it relates to clean technology development. The three individual value proposition statements developed as part of the study follow.

ENERGY TRANSITION VALUE PROPOSITION: ALBERTA

Alberta is uniquely positioned to bridge the transition to a low-carbon economy. Rich in natural resources and serving as Canada's energy powerhouse, Alberta has a long history of carbon policies and an established, sophisticated carbon market, creating favourable deployment conditions for clean technology. Alberta has had an industrial carbon pricing system in place since 2007 and has transacted over 15 megatonnes of compliance-quality, nature-based climate solutions since its creation.[168]

Alberta is home to one of the largest industrial centres in Canada, which includes a high concentration of energy companies shifting their focus toward decarbonization and a clean energy transition. Currently, 75 percent of all clean technology investments by Canadian companies ($1.4 billion annually) come from the oil and natural gas sector[169] – and that number is only expected to grow. A formal alliance, Oilsands Pathway to Net Zero[170], was launched in July 2021 by the province's largest energy companies – Canadian Natural Resources Limited, Cenovus Energy, Imperial Oil, MEG Energy and Suncor Energy. To achieve net zero in Alberta, it is estimated that heavy industry will need to invest more than $2.2 billion in cleantech development and deployment annually by 2030, rising to $5.4 billion annually by 2040.[171] With this investment, it is estimated that by 2040 the cleantech sector will contribute $15 billion to Alberta's GDP, a massive market opportunity.

The cleantech ecosystem in Alberta is strengthened by world-class laboratories and test centres, such as the Water Technology Development Centre,[172] C-FER Technologies,[173] the Centre for Grid Innovation[174] and the CanmetENERGY Devon Research Centre,[175] as well as top-ranking universities. The University of Alberta consistently ranks on the global top 100 universities list and ranks 3rd globally as an Artificial Intelligence research centre[176]. Clean technology development is also supported by strong public grant programs, including Alberta Innovates, which will invest $159 million in clean technology projects in 2021[177], and Emissions Reduction Alberta (ERA). ERA is a unique provincial funding structure that leverages industrial carbon levies to support projects that drive heavy industry emission reductions.[178] Over the past decade ERA has provided $646 million in funding to over 204 emission reduction projects across Alberta.[179]

Alberta is also home to some of the most livable and safe cities in the world,[180] with easy access to the Rocky Mountains and world class national and provincial park systems, affordable residential and commercial real estate and high-quality education and healthcare. Alberta also boasts some of the most business-friendly policies in North America, including a low corporate tax rate, currently at just 8 percent - the lowest in Canada.[181]

Alberta has a long history of collaboration, capital deployment and resource mobilization to execute large-scale, innovative projects, such as the development of the steam-assisted gravity drainage (SAGD) technology, a transformational, multibillion-dollar oil sands initiative.[182] Alberta is ready for our next great challenge: the energy transition.

ENERGY TRANSITION VALUE PROPOSITION: CALGARY

Calgary is Canada's innovation hub, with the highest concentration of high-tech workers, proportion of STEM graduates and labour force productivity of all major Canadian cities.[183] Calgary is also home to the most head offices per capita of any major Canadian city,[184] including utilities, telecommunication providers, transportation and logistics operators and virtually all major Canadian energy companies. This density and diversity means direct access to customers and decision-makers. Technology developers are taking notice of this unique advantage, with 70 percent of Alberta's cleantech firms based in Calgary.[185] Calgary is considered to be one of the top 15 markets for cleantech development globally. The city's holistic start-up ecosystem, talent pool and cleantech focus have the potential to make Calgary an energy transition leader.

Its key laboratories and test centres, such as the Alberta Carbon Conversion Technology Centre (AC-CTC)[186], the Avatar Energy Transition Centre,[187] Exergy Solutions[188] and the Advancing Canadian Wastewater Assets (ACWA) Laboratory[189] at Pine Creek, are accelerating the pace of commercialization of new ventures, complementing Edmonton's manufacturing and industrial heartland narrative. Strong government and public support for local research and expertise also makes access to land for testing and development significantly easier than in other jurisdictions.

The Economist's 2019 Global Livability Index[190] ranked Calgary the fifth most livable city in the world. It offers premium office and industrial space (with amazing views of the Rockies), a strong complement of support services (IT, engineering, legal) and a highly integrated transportation and logistics system.

Calgary is an entrepreneurial hot spot in Canada, consistently ranking on Start-up Genome's Emerging Ecosystem List.[191] The 2021 Start-up Genome report ranked Calgary 2nd place in the National 'Bang for Buck' Ecosystem category[192]. Calgary boasts

[168] Pricing Carbon Pollution in Alberta_Mar2019_final (pembina.org)
[169] Canadian oil and natural gas is a cleantech industry - Context Magazine by CAPP
[170] Oil Sands Pathways to Net Zero - Helping Canada achieve its climate goals
[171] Source: Delphi's future market growth assessment economic model
[172] The Water Technology Development Centre | Canada's Oil Sands Innovation Alliance - COSIA
[173] Home | C-FER TECHNOLOGIES (cfertech.com)
[174] Centre for Grid Innovation - Industry Solutions (nait.ca)
[175] CanmetENERGY in Devon (nrcan.gc.ca)
[176] ai | Research + Innovation (ualberta.ca)
[177] https://albertainnovates.ca/wp-content/uploads/2021/06/Alberta-Innovates-2021-24-BUSINESS-PLAN_Final.pdf
[178] Technology Innovation and Emissions Reduction Regulation | Alberta.ca
[179] Impact - Emissions Reduction Alberta (eralberta.ca)
[180] Liveability-Free-report-2019.pdf (cbeinternational.ca)
[181] Federal and Provincial-Territorial Tax Rates for Income Earned by a CCPC – 2020 and 2021 (home.kpmg)
[182] Alberta Oil Sands Technology and Research Authority - Oil Sands - Alberta's Energy Heritage
[183] PowerPoint Presentation (calgaryeconomicdevelopment.com)
[184] PowerPoint Presentation (calgaryeconomicdevelopment.com)
[185] Startup Genome
[186] Alberta Carbon Conversion Technology Centre (ACCTC) - InnoTech Alberta
[187] General 4 — Avatar Innovations
[188] Agile Engineering and 3D Printing Experts - Get Exergy working for you! (exergysolutions.com)
[189] Laboratories | Research at UCalgary | University of Calgary
[190] Liveability-Free-report-2019.pdf (cbeinternational.ca)
[191] Startup Genome
[192] Startup Genome

a strong support network of post secondary-institutions including the University of Calgary, SAIT and Mount Royal University, co-working spaces (Assembly[193], EFFECTIV[194], ResourceYYC[195], WorkNicer[196]), business accelerator programs (The Accelerator[197], Platform[198], Plug and Play[199], SVG Thrive[200] GreenSTEM[201]) and an emerging financing nucleus. Over the past decade, the Calgary region has undergone a profound shift in the way it seeks to support its entrepreneurs and create a culture of innovation. Programs such as Rainforest Alberta,[202] Creative Destruction Lab (CDL)-Rockies[203] and collaborative networks such as the Central Alberta Regional Innovation Network (CARiN)[204] and the Clean Resource Innovation Network (CRIN)[205] have allowed a shift in mindset in the region, promoting a culture of collaboration.

Calgary is emerging as an ag-tech expertise and talent centre. Institutes such as Olds College[206], the University of Lethbridge[207], and the Integrated Agriculture Technology Centre at Lethbridge College[208] have unparalleled technical capabilities across the agribusiness supply chain. Alberta's proven success with carbon tax and carbon marketplace mechanisms also lends itself well to agriculture's carbon offset and nature-based sequestration potential. With a growth projection of 13 percent year-over-year, Calgary's agribusiness sector is forecast to invest $246 million in digital transformation by 2024[209], while agtech globally is forecast to become a $725 billion (USD) industry by 2023[210]. With its history of farming, skilled workforce, world-class academic and research institutions, and renowned entrepreneurial spirit, Calgary is poised for significant growth and investment in ag-tech.

ENERGY TRANSITION VALUE PROPOSITION: EDMONTON METROPOLITAN REGION

The Edmonton Metropolitan Region is the manufacturing and industrial heartland of Alberta, with GDP, income and population growth expanding by three times the Canadian average over the past five years.[211] The Edmonton region is also home to a thriving technology ecosystem. The CBRE's 2021 Scoring Tech Talent Report ranked Edmonton as the fastest growing tech ecosystem in North America.[212]

Home to Western Canada's largest manufacturing hub,[213] the region is the gateway to Canada's north , a strategic advantage when accessing Asian markets.

The Edmonton region's robust research ecosystem and post-secondary institutions, such as the Northern Alberta Institute of Technology (NAIT)[214] and the University of Alberta (which is ranked among the top 100 post-secondaries in the world for graduate employability)[215] support its clean technology expertise in carbon capture, utilization and storage (CCUS); hydrogen production; and digitalization. In 2018 Edmonton was ranked as one of the Top 100 Best Cities to Live globally.[216] Edmonton, is an exceptionally livable city, with affordable real estate and access to high-quality education and healthcare. The region's 14 municipalities are individually unique, include a population of 1.4 million and are bursting with potential.

The Edmonton Metropolitan Region is home to Canada's first and largest hydrogen hub,[217] which builds off its extensive CCUS expertise. The Edmonton region is one of the largest producers of hydrogen globally and has deep technical expertise in producing low-cost and low-emission hydrogen – in addition to having well-established energy transportation, pipeline and CCUS infrastructure, such as the ACTL (Alberta Carbon Trunk Line)[218], the world's largest CO2 pipeline. With a robust R&D-to-commercialization pipeline, concentration of heavy industry, transportation corridor, and considerable government support for large-scale projects[219] – such as Air Products' $1.3 billion net zero hydrogen energy complex[220] – the region has a built-in hydrogen market. This in turn will position the region to capitalize on the large potential export market for hydrogen. Sixty-six countries have 2050 net zero targets[221] and hydrogen is being included in short, medium and long-term planning. Key industrial players plan to increase hydrogen investment six-fold by 2025, with a potential for a 16-fold increase in investment by 2030.[222]

The Edmonton region has established itself as a leading artificial intelligence (AI) and machine learning (ML) research cluster, backed by strong post-secondary and research capabilities and a thriving startup ecosystem. The region is home to dozens of startups leveraging artificial intelligence innovation – in the last few years these companies have raised hundreds of millions. The region is home to the University of Alberta, which is ranked 3rd in artificial intelligence research globally[223], and the Alberta Machine Intelligence Institute, part of the Pan-Canadian AI Strategy.[224] Edmonton was rated as an AI up-and-comer by Global Startup Ecosystem[225] and has already attracted corporate investment from major global players like Google and Amazon.[226] A built-in local market and strong pool of first customers for digital technologies can be found in Alberta's industrial base, many of whom are looking to drive efficiency and productivity and transform how they do business. A close proximity to customers and access to extensive data sets also creates a natural feedback loop for algorithm refinement and accelerated development. Navius Research estimates that the annual growth rate within the digitalization sector will reach 18 per cent over the next decade, spurred locally by digital oil field applications and large market opportunities across a wide range of economic sectors.

[193] Assembly Coworking Space | Tech Start-ups and Small Business | Calgary (assemblycs.com)
[194] About Us – EFFECTIV | Calgary coworking space
[195] ReSourceYYC | Calgary Coworking Office Space for Professionals
[196] Work Nicer Coworking | Calgary & Edmonton Coworking Community
[197] THE ACCELERATOR | CALGARY ALBERTA SEED ACCELERATOR
[198] Home » Platform Calgary
[199] Plug and Play Alberta – Plug and Play Tech Center
[200] SVG Ventures | THRIVE launches in Canada and establishes their innovation and investment platform with headquarters in Calgary, Alberta - THRIVE (thriveagrifood.com)
[201] GreenSTEM | Alberta.ca
[202] Rainforest Alberta - HOME PAGE (rainforestab.ca)
[203] Calgary - Creative Destruction Lab
[204] HOME - Central Alberta Regional Innovation Network (ca-rin.ca)
[205] Clean Resource Innovation Network (CRIN)
[206] Research & Innovation (oldscollege.ca)
[207] Welcome to the University of Lethbridge | University of Lethbridge (ulethbridge.ca)
[208] Integrated Agriculture Technology Centre | IATC at Lethbridge College
[209] Agri-business (calgaryeconomicdevelopment.com)
[210] Dentons - Agtech and AI – influential agribusiness trends in Alberta
[211] Economic Strength | City of Edmonton - Industrial (edmontonindustrial.ca)
[212] Edmonton region a top destination for tech company expansion - Edmonton Global
[213] 2017-Heartland-Industrial-Guide-FINAL.pdf (industrialheartland.com)
[214] NAIT - A leading polytechnic committed to your success
[215] U of A graduates rank among most employable in the world | Folio (ualberta.ca)
[216] World's Best Cities - Best Cities
[217] Canada's first Hydrogen Hub: Boosting economy, creating jobs, tackling climate crisis - Ryze Hydrogen
[218] Alberta Carbon Trunk Line - Alberta Major Projects
[219] Alberta: Government is Charting A New, Diversified Future For The Natural Gas Sector And Hydrogen Playing A Leading Role - FuelCellsWorks
[220] Air Products Announces Multi-Billion Dollar Net-Zero Hydrogen Energy Complex in Edmonton, Alberta, Canada
[221] United Nations: Sixty-Six Countries Committed To Net Zero CO2 Emissions By 2050 (ndtv.com)
[222] https://hydrogencouncil.com/en/hydrogen-deployment-accelerating-with-more-than-300-billion-in-project-pipeline/
[223] David Staples: Edmonton leading way in artificial intelligence research | Edmonton Journal
[224] Alberta Machine Intelligence Institute | AI for good and for all (amii.ca)
[225] Investing in AI is good business for Alberta | Alberta School of Business (ualberta.ca)
[226] Artificial Intelligence - Edmonton Global

COMMENTARY

Alberta and its core urban centers – Calgary and the Edmonton Metropolitan Region – offer clean technology investors several benefits including affordable housing and a high quality of living. Alberta's extensive energy sector infrastructure complements many energy transition technology pathways, including hydrogen, CCUS and energy storage, potentially accelerating pilot project and demonstration timelines in these areas.

Alberta's oil and gas sector is one of the largest investors in clean technology in Canada and the sector continues to implement leading technologies to drive annual emission reductions and operational efficiencies. One of the largest challenges likely lies in changing the Alberta energy sector narrative to an energy transition narrative. This is a conversation that has been taking place over the last decade and while inroads have been made, Alberta's reputation as solely an oil and gas producer persists,

When we look at the size, primary industries and landscape of the city of Calgary and the Edmonton Metropolitan Region, they appear to be quite similar. However, there are nuances between the regions that this study was able to draw out. For example, the Calgary region has focused its efforts on creating a collaborative start-up ecosystem that works across many entities and organizations to support new ventures. This nuance was cited several times throughout the stakeholder interview process; the work being done to create a culture of innovation within the region is not going unnoticed.

Calgary's start-up ecosystem is beginning to mature, and it is consistently being recognized by organizations like Start-up Genome. The development of a strong start-up ecosystem and support network will make Calgary a desirable destination for start-ups working across a wide spectrum of markets. The work Calgary has done to develop this ecosystem will also lend itself naturally to organizations in the clean or emerging economy. This ecosystem, combined with Calgary's access to decision-makers and industrial customers, make it a strong candidate for a clean technology headquarters. Calgary is also emerging as an ag-tech specialist, given the proximity to research centers and educational institutions working on developing agricultural solutions.

On the other hand, the Edmonton Metropolitan Region has strong and growing clusters in hydrogen, CCUS and digital technologies. The Edmonton Metropolitan Region offers world-class access to industrial infrastructure and clean technology demonstration sites. The proximity to pilot sites in Alberta's oil sands and decision-makers make the Edmonton Metropolitan Region a strong choice for start-ups developing energy transition technologies. The Edmonton region's start-up ecosystem is also beginning to mature and is beginning to move into a period of growth. A recent CBRE Group study found that Edmonton has one of the fastest growing tech ecosystems in North America.[227]

[227] Source: Latest CBRE report shows Canada has some of the fastest-growing tech talent pools in North America | BetaKit

FUTURE ENERGY TRANSITION OPPORTUNITIES

This report contains a great deal of information about Alberta's clean technology ecosystem and clean economy. But what does it all mean in terms of where Alberta's strengths lie and what opportunities we should be focusing on?

Based on Alberta's current assets and areas of strengths, there is a clear opportunity to bridge the province's energy sector through the energy transition. Development of clean technology sub-sectors can utilize energy sector assets to accelerate commercialization and decarbonization, specifically hydrogen production and utilization, as well as CCUS. Several technology pathways, including energy efficiency, digitalization, and electrification, should also be a focus for the province, as these sub-sectors need to be developed in concert to reduce impacts from the energy sector while helping unlock larger plays like hydrogen and CCUS more quickly. Lastly, given Alberta's expertise and reputation as an agriculture centre, not only within Canada but globally, there is significant opportunity for Alberta to develop ag-tech solutions for in-house use and global export.

> *Alberta's urban hubs operate effectively in tandem. Calgary, with its proximity to head office decision-makers and high density of clean-tech ventures, is developing clean technology that can find local deployment sites and first customers within the EMR's Industrial Heart-land.*

If Alberta was to pursue a net zero pathway for the province and focus further investment on in-house clean technology development, it would add significant jobs and GDP compared to a business-as-usual scenario. The traditional pathway would generate $4 billion in GDP and add 20,000 jobs in 2050, assuming predicted growth trends continue at the same rate. This is contrasted with $61 billion in GDP and 170,000 new jobs if the focus is on the cleantech opportunity. The study's analysis estimates that a net zero pathway in Alberta would require more than $2.1 billion in annual capital investment by 2030. That number will increase to $5.5 billion annually by 2040.

> *By 2050, a net zero growth pathway could generate almost 170,000 new clean technology jobs and contribute $61 billion in GDP.*

A strong focus on developing the skillsets needed to build out Alberta's future workforce will be essential to strengthen Alberta's clean economy. Reskilling and training programs for energy sector workers should play a role in this transition. Many energy sector skills naturally lend themselves to the cleantech sector, which means that Alberta has an advantageous position when it comes to talent access. Bringing in new skillsets, currently not present in the province, should also be a priority. Alberta's affordable real estate market, high standard of living and world-class recreation access will be important selling features when trying to bring top talent to the province.

> *Energy efficiency, digitalization, and electrification need to be a focus for the province as sub-sectors that should be developed in concert to reduce impacts from the energy sector while accelerating the unlocking of larger plays like hydrogen and CCUS.*

From a cleantech development perspective, both Calgary and the Edmonton Metropolitan Region are emerging as focal points within Canada. Alberta's urban centers have taken different approaches to how they want to capitalize on their respective cleantech opportunities; however, the approaches complement one another. The Edmonton region, which includes Alberta's Industrial Heartland, is within close proximity to industrial infrastructure and assets, including refineries and pipeline networks. These assets create a natural development and deployment area for hard-tech solutions like hydrogen and CCUS. The Edmonton Metropolitan Region is also looking to set itself apart from competing jurisdictions by creating deep expertise within emerging technology pathways, such as AI and ML.

Calgary on the other hand is taking a slightly different approach in that it is seeking to build out a strong start-up ecosystem that can support ventures across the spectrum of 'cleantech'. Calgary is less hub-focused and instead concentrating its efforts on becoming a strong overall innovation ecosystem. This is seen by the fact that currently 70 percent of Alberta's cleantech companies are headquartered in Calgary. It was also ranked as a top 15 cleantech market by Start-up Genome.

> *The province is sending positive signals to investors that clean technology development is a priority, including net zero targets and commitments from oil and gas companies, strong small business practices and low taxation rates, strong public funding programs for emerging technology and investment in leading research institutions and test facilities to accelerate commercialization timelines*

Both approaches, although unique, operate effectively in tandem. Calgary, with its proximity to head office decision-makers and high density of cleantech ventures, is developing clean technology that can find local deployment sites and first customers within the EMR's Industrial Heartland. Together, both urban centres are creating a natural innovation corridor within Alberta.

To achieve the capital investment required for a successful net zero pathway in Alberta, significant foreign direct investment (FDI) will be needed. At this time, some negative signals are being sent to investors that may indicate that the energy transition and serious pursuit of clean technology development is not a priority for Alberta. This includes the cancellation of the Alberta Investor Tax Credit, the closure of Alberta's provincial energy efficiency agency – Energy Efficiency Alberta and the provincial government's decision to repeal Alberta's carbon tax.

Despite these headlines, it doesn't tell Alberta's complete cleantech story. The province is sending positive signals to investors that clean technology development is a priority, including net zero targets and commitments from oil and gas companies, strong small business practices and low taxation rates, strong public funding programs for emerging technology and investment in leading research institutions and test facilities to accelerate commercialization timelines. For Alberta to maintain a cleantech leadership position, strong, consistent climate policy and leadership will be needed, as it will be key to securing FDI for Alberta's cleantech ventures and large-scale technology demonstration projects.

Research and stakeholder engagement for this study yielded several recommendations to strengthen Alberta's cleantech ecosystem and to capitalize on Alberta's leadership position in the clean economy, including:

Improve the presence of local investment/investors, including venture capital (VCs) and angels.

Several stakeholders cited a lack of local investment presence as a reason for relocating their company. Alberta has seen a number of new investment firms emerge in the last 18 to 24 months, however more local investment is needed to keep ventures based in Alberta. It was also noted that capital access tends to be better for start-ups than scale-ups and that investment for scaling ventures should be prioritized.

Continuing efforts to encourage technology piloting and demonstration projects

This will not only give local technology companies a faster path to scale but also de-risk investments for external or foreign investors. While local capital appears to only be enough to support early-stage development of technology companies, there is evidence that corporate incumbents will participate in financing rounds for notable companies.

A renewed focus on bringing new talent to the province will be needed if Alberta is to take a leadership role within cleantech. Quality of living and world-class mountain landscape access are strong selling features to skilled young talent.

Skilled youth are choosing investment hot spots, like Toronto, Vancouver and Seattle, over cities like Calgary and the Edmonton Metropolitan Region. This is particularly true for skilled workers and talent that have recently graduated. This age group is less focused on real estate ownership and therefore willing to relocate to investor-heavy cities despite the added cost of living.

A program designed to connect cleantech ventures with first customers would benefit the province significantly.

This includes the development of municipal and Crown Corporation local-first deployment programs, with financial incentives to help offset the perceived risk of pilot/demonstration projects. As mentioned throughout the report, there is no shortage of potential first customers within Alberta. The willingness of customers to pilot or deploy new technology remains an issue.

More connections to market and early connections with demand owners can support the transfer of university-developed technology into the market through spin-outs and technology transfer agreements.

The research ecosystem in Alberta is strong, with universities that are undertaking research in areas critical to the energy transition. ESG leadership can also play a key role in continuing to recognize the talent, diversity and excellence of the people in this province, who have the skills and determination to address our biggest challenges and seize on our greatest opportunities.

Establishing footholds beyond project deployment, and focused on development of technologies critical to the energy transition.

Building new strengths in technology locally will keep talent in the province, improve inbound FDI, and ultimately create jobs and economic development.

Given the large potential of these technology pathways within Alberta, a more robust telecommunication system would benefit deployment and commercialization opportunities within these particular sectors.

Rural areas throughout the province still struggle with broadband network quality. This remains a potential barrier to the deployment of both ag-tech and digital oilfield solutions, which would be deployed in rural settings and require strong wireless or broadband networks to successfully deploy.

Alberta could demonstrate net zero leadership by driving alternative, sustainable product adoption with updated green procurement practices and product certifications.

Currently there is a lack of regulatory certainty, reliable incentives, and investment credits to reduce the capital-intensive investments required for large-scale CCUS projects. Similarly, as new carbon-derived products and alternatives begin to emerge, industrial codes, product standards and green building/infrastructure rating systems will need to evolve to encompass these new solutions.

A narrative has begun to emerge about the carbon-impact of blue hydrogen. Alberta will need to begin to transform and control this narrative if hydrogen is to remain a part of a net zero and energy transition pathway.

This should include increased marketing about the environmental benefits of hydrogen utilization and the role hydrogen has to play in clean energy generation.

Increasing the percentage of renewable energy on Alberta's grid will help drive further uptake of electrified technologies, which stand to benefit from a lower-emitting grid.

Alberta's electricity grid is one of the most carbon-intensive in Canada, although it also has one of the highest potential renewable energy capacities in the country, and will need to do this if it wants to remain competitive in the electrification space against other Canadian jurisdictions.

There is an opportunity to incorporate electrification into comprehensive climate, transportation and infrastructure plans – which are currently all standalone strategies

Increased collaboration between government departments will enable clean technology deployment opportunities by creating an environment that supports the uptake of emerging technology pathways.

Consistent, strong climate policy and ESG leadership, including an overarching hydrogen utilization strategy, is needed to create a 'north star' that guides clean technology development in Alberta.

This, perhaps more than other recommendation within the report, was strongly endorsed by the project's key stakeholders and Advisory Committee.

APPENDIX A

Project Methodologies

ECONOMIC MODEL

The economic model for the study was developed using multiple statistical data sets – Statistics Canada's Environmental and Clean Technology Products Economic Account (ECTPEA) and business counts for Alberta, and HS Commodity Code-linked data. Together, these economic datasets measure the economic contribution of environmental and clean technology products in terms of output, gross domestic product (GDP), employment (i.e., number of jobs), and international trade (i.e., export-generated revenue). Jobs, real GDP, and export revenue were estimated by analyzing specific industries in the Alberta provincial business accounts that are operating in the cleantech space.

The Statistics Canada cleantech economic dataset and Alberta business counts were useful at the macro level, but a more granular level of detail was required for this study to determine the economic contribution of the 16 selected energy transition technology sub-sectors. This was accomplished by refining the HS Commodity Codes used to better match clean technology development and clean economy activities across the 16 sub-sectors. Considerable research in identifying clean HS codes has taken place over the past 20 years and this research is continuing today. The United States Trade Administration (USTA), the World Trade Organization (WTO), Asia-Pacific Economic Co-operation (APEC), the Organization for Economic Co-operation and Development (OECD), and Statis-tics Canada have all been working to classify cleantech export and import activities with best-fit HS Commodity Codes. These classifications are accepted globally.

It is important to note that some NAICS codes were mapped to more than one sub-sector and in such cases the duplication has been netted out. GDP and job numbers have been filtered through intensity ratios at the industry level developed by Statistics Canada for Alberta. For the waste management and advanced recycling technologies sub-sector, only estimates for remediation and material recovery materials (recycling) were included. Activities for waste collection and disposal were excluded.

FUTURE GROWTH ANALYSIS ECONOMIC MODEL

The future-facing economic model utilized the same NAICS codes and definitions as the baseline model to bound the scope of the sub-sectors analyzed. The future market growth assessment developed an annual growth rate for each sub-sector using several forecasts from established sources, including McKinsey (global), Navius Research (local), SNC Lavalin (global), Bloomberg (global), the International Energy Agency (IEA) (global) and the AESO (Alberta Energy Systems Operator) (local). A blend of localized and global growth rates was used to develop an averaged, unique growth factor for each cleantech sub-sector. A summary of the average annual growth rate used for each sub-sector can be found in the Table A1 below.

VALUE PROPOSITION DEVELOPMENT

Key findings and stakeholder feedback generated from the SWOT Analysis and Ecosystem Bench-marking Analysis were used as the foundation for the value propositions. Additional research was conducted to fill in gaps and provide evidence to support stakeholder claims. Three SMEs also provided their direct feedback via a primary interview process. The companies provided their perspective on the advantages Alberta, Calgary and the Edmonton Metropolitan Region offer to prospective founders and business owners who may be looking to relocate their cleantech companies. The interviews were developed into accompanying case studies, not published in this report.

A draft value proposition was developed for each of the 3 identified regions and presented to a group of key stakeholders (i.e., Advisory Committee) to gauge their initial reactions to the statements and gather further insight on the strengths that should be highlighted for each unique statement. Stakeholders were also asked if the statements told an accurate narrative and were asked if the narrative rang true based on their own experiences within the ecosystem. There was a consensus that the narratives were true and accurate, with a need for more examples to demonstrate the claims within the statements.

Table A1 - Net Zero Growth Projection Trends, by Sub-Sector

Net Zero Annual Rate of Growth Projection Trends by Select Consultancies & Agencies	**McKisey** (2020 -2030)	**SNC** (2020 -2050)	**Blooberg** (2020 -2050)	**AESO** (2021 -2041)	**EIA** (2020 -2030)	**EIA** (2020 -2050)	**Navius** (2020 -2030)	**Average**
Digitalization						1.31	1.18	1.24
Carbon capture, utilization and storage						1.19		1.19
Methane monitoring and abatement							1.18	1.18
Energy storage technologies			1.11	1.22		1.19		1.17
Hydrogen production and utilization						1.09		1.09
Sustainable, alternative and high-tech materials						1.06	1.11	1.08
Energy efficiency				1.01			1.13	1.07
Renewable energy production		1.0775	1.08	1.03		1.10	1.06	1.07
Small Modular Reactor (SMR)		1.05	1.10			1.02		1.06
Sustainable fuel development						1.05	1.04	1.05
Electrification			1.05	1.03				1.04
Waste management and recycling	1.03							1.03
Water efficiency and wastewater treatment technologies	1.03							1.03
Ag-tech and agriculture	1.03							1.03
Non-thermal use of fossil-based feedstocks					1.03			1.03

APPENDIX B

Table B1. Cleantech Sub-sector Definitions:

Sub-sector	Definition – i.e. technology areas the sub-sector includes
Carbon capture, utilization and storage	Low-carbon concrete, direct air capture and carbon sequestration technologies and infrastructure
Energy efficiency	Cogeneration, high-performance HVAC equipment, energy management and energy-efficient products/services (e.g. lighting)
Renewable energy generation	Projects and facilities that generate renewable energy from solar, wind, geothermal and run-of-river hydro
Hydrogen	Hydrogen value-chain, including production, use and transportation technologies. Hydrogen fuel cells and material development are included.
Waste management and advanced recycling technologies	Materials recovery and remediation services/technologies
Electrification	Electrical grid infrastructure, including smart grid enhancement, and the development of transportation infrastructure/technologies such as EV charging and rail line electrification
Sustainable fuel development	Sustainable fuel production, including aviation fuels, ethanol, biodiesel, renewable natural gas and biogas
Methane monitoring and abatement	Technologies that monitor emissions (e.g. sensors, surveillance, cameras) and abate emission releases (leak prevention solutions for pipelines, flare units)
Small modular reactors	Modular nuclear systems designed for localized power generation, such as for oil sands operations
Ag-tech and agriculture	Technologies to improve the yield and efficiency of agricultural operations and to create alternative products.
Energy storage	Technologies, materials and supply chain. Batteries, compressed air and pumped hydro are included.
Sustainable, alternative and high-tech materials	Covers biochemicals, alternative bitumen products such as bitumen beyond combustion pathways, bioplastics, biopharma and engineered forest products
Water efficiency and wastewater treatment	Technologies that reduce water consumption – commercial and residential – and improve the effectiveness and efficiency of wastewater treatment, especially contamination and heavy metal processing
Digitalization	Covers a wide-range of technologies that increase the digital capacity and efficiency of various sub-sectors, including sensors, data analytics, artificial intelligence, machine learning, IoT, data management, software solutions and augmented/virtual reality applications such as digital twins and training

Table B2: Cleantech Subsector and NAICS Codes

Sub-sector	NAICS			
Carbon capture, utilization, and storage	Basic chemical manufacturing [3251]	Cement and concrete product manufacturing [3273]	Agricultural, construction and mining machinery manufacturing [3331]	
Energy efficiency (e.g., co-generation, high-performance HVAC equipment)	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing [3334]			
Renewable energy production (solar, wind and hydro)	Electric power generation, transmission and distribution [2211]	Hydro-electric power generation [221111] Fossil-fuel electric power generation [221112] Other electric power generation [221119] Electric bulk power trans-mission and control [221121] Electric power distribution [221122]		
Energy storage technologies, materials, and supply chain (e.g., lithium extraction)	Other electrical equipment and component manufacturing [3359]	Detailed Pumped Hydro Storage & Compressed Air and components have been added.		
Hydrogen production and utilization (sector will cover various aspects of hydrogen-related technology including fuel cells, storage, transportation, materials development)	Motor vehicle body and trailer manufacturing [3362]	Natural gas distribution, water, sewage and other systems [221A] 42	Basic chemical manufacturing [3251]	Other electrical equipment and component manufacturing [3359]
Waste management and advanced recycling technologies	Waste management and remediation services [562]			
Electrification (including vehicle and rail electrification technologies) and grid infrastructure, including smart grid capabilities	Electric power generation, transmission and distribution [2211]	Other engineering construction [23C5] 43	Boiler, tank and shipping container manufacturing [3324]	
Sustainable fuel development, including transportation fuels (e.g., aviation, biodiesel, biogas and renewable natural gas				
Renewable Natural Gas (RNG)	Petroleum re-fineries [32411]			
Wood Fuel	Sawmills and wood preservation [3211]			
Biofuels	Basic chemical manufacturing [3251]			

Sub-sector	NAICS			
Aviation Fuel	Petroleum re-fineries [32411]			
Small Modular Reactor (SMR) development (i.e., modular nuclear)	Scientific research and development services [5417]			
Methane monitoring and abatement	Other electronic product manufacturing [334A] 55			
Digitalization (IoT, sensors, data analytics, AI, machine learning, AR/VR/digital twins, data management)	Computer and peripheral equipment manufacturing [3341]	Data processing, hosting, and related services [518]		
Water efficiency and wastewater treatment technologies	Water, sewage and other systems [2213]			
Ag-tech and agriculture	Support activities for forestry [1153]	Support activities for crop and animal production [115A] 9	Agricultural, construction and mining machinery manufacturing [3331]	Scientific re-search and development services [5417]
Non-thermal use of fossil fuel feedstocks and sustainable, alternative and high-tech materials (e.g., biochemicals, bio-plastics, biopharmaceuticals, pipeline coatings)				
Non-thermal	Petroleum and coal product manufacturing (except petroleum refineries) [BS3241A0]			
BioPharma	Pharmaceutical and medicine manufacturing [3254]			
Bioplastics	Resin, synthetic rubber and fibres, and paint manufacturing [325B] 51			
Biochemicals	Basic chemical manufacturing [3251]			
Engineered Forest Products	Sawmills and wood preservation [3211]			
Cellulose	Sawmills and wood preservation [3211]			

Note: Double counting was avoided for NAICS codes which were included in more than one sub-sector.

Table B3: Job and GDP Intensity Ratios (Statistics Canada)

Sub-sector	Job Intensity Ratios	GDP Intensity Ratios
Carbon capture, utilization, and storage	0.5 percent	0.6 percent
Energy efficiency (e.g., co-generation, high-performance HVAC equipment)	11.8 percent	14.9 percent
Renewable energy production	9.0 percent	6.4 percent
Energy storage technologies, materials and supply chain (e.g., lithium extraction)	100.0 percent	100.0 percent
Hydrogen production and utilization (sector will cover various aspects of hydrogen-related technology including fuel cells, storage, transportation, materials development)	6.6 percent	5.6 percent
Waste management and advanced recycling technologies	95.1 percent	95.3 percent
Electrification (including vehicle and rail electrification technologies) and grid infrastructure, including smart grid capabilities	7.1 percent	7.2 percent
Sustainable fuel development, including transportation fuels (e.g., aviation, biodiesel, biogas and renewable natural gas	6.9 percent	3.2 percent
Small Modular Reactor (SMR) development (i.e., modular nuclear)	13.5 percent	17.9 percent
Methane monitoring and abatement	9.6 percent	13.5 percent
Digitalization (IoT, sensors, data analytics, AI, machine learning, AR/VR/digital twins, data management)	13.3 percent	17.3 percent
Water efficiency and wastewater treatment technologies	95.1 percent	100.0 percent
Ag-tech and agriculture	11.6 percent	9.1 percent
Non-thermal use of fossil fuel feedstocks and sustainable, alternative and high-tech materials (e.g., biochemicals, bioplastics, biopharmaceuticals, pipeline coatings)	18.6 percent	4.6 percent
TOTAL	**14.2 percent**	**9.8 percent**

Sub-sector	Exoprts	Imports
Carbon, Capture, Utilization & Storage	$110	$77
Energy efficiency	$401	$234
Renewable energy production	$14	$388
Energy storage technologies	$31	$51
Hydrogen production and utilization	$10	$1
Waste management and recycling	$254	$157
Electrification	$140	$215
Sustainable fuel development	$215	$58
Small Modular Reactor (SMR)		$0
Methane monitoring and abatement	$70	$99
Digitalization	$246	$280
Water efficiency and wastewater treatment	$121	$187
Ag-tech and agriculture	$102	$69
Non-thermal use and sustainable materials	$3,035	$133
TOTAL	**$4,749**	**$1,950**

Table B4: Summary of Clean Technology GDP and Jobs, by Clean Technology Subsector, Alberta

Sub-sector	GDP (Millions of 2012 Dollars)	GDP Annual Growth 2016 to 2020	Jobs	Jobs Annual Growth 2016 to 2020
Carbon capture, utilization, and storage	$44	-7.8 percent	220	-6.8 percent
Energy efficiency (e.g., co-generation, high-performance HVAC equipment)	$442	-0.3 percent	3,524	1.9 percent
Renewable energy production	$325	0.9 percent	1,173	-2.1 percent
Energy storage technologies, materials, and supply chain (e.g., lithium extraction)	$59	2.4 percent	461	-1.5 percent
Hydrogen production and utilization (sector will cover various aspects of hydrogen-related technology including fuel cells, storage, transportation, materials development)	$120	18.7 percent	211	6.9 percent
Waste management and advanced recycling technologies	$318	-1.3 percent	2,449	4.3 percent
Electrification (including vehicle and rail electrification technologies) and grid infrastructure, including smart grid capabilities	$191	-2.7 percent	1,157	8.3 percent
Sustainable fuel development, including transportation fuels (e.g., aviation, biodiesel, biogas and renewable natural gas	$377	-17.6 percent	1,406	6.9 percent
Small Modular Reactor (SMR) development (i.e., modular nuclear)	$16	-12.4 percent	115	-12.4 percent
Methane monitoring and abatement	$47	18.5 percent	117	-6.7 percent
Digitalization (IoT, sensors, data analytics, AI, machine learning, AR/VR/digital twins, data management)	$38	-5.9 percent	174	-11.2 percent
Water efficiency and wastewater treatment technologies	$492	1.1 percent	989	6.6 percent
Ag-tech and agriculture	$99	-2.6 percent	1,270	-6.8 percent
Non-thermal use of fossil fuel feed-stocks and sustainable, alternative and high-tech materials (e.g., biochemicals, bioplastics, biopharmaceuticals, pipe-line coatings)	$186	-2.1 percent	1,386	19.5 percent
TOTAL	**$2,753**	**-3.5 percent**	**14,651**	**2.4 percent**

Sources: Statistics Canada Table 36-10-0402-01 Gross domestic product (GDP) at basic prices, by industry, provinces and territories (x 1,000,000) https://doi.org/10.25318/3610040201-eng and; Statistics Canada. Table 36-10-0489-01 Labour statistics consistent with the System of National Ac-counts (SNA), by job category and industry https://doi.org/10.25318/3610048901-eng

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Carbon Capture Utilization & Storage (CCUS)	Utilization of Existing, Near or Medium term Projected Captured Carbon Supply (CarbonTech)	HS 280300 - Carbon (Carbon Blacks and Other Forms of Carbon Nes)	HS 380210 - Activated Carbon	HS 847432 - Machines For Mixing Mineral Substances With Bitumen	HS 730410 - Line Pipe of A Kind Used For Oil or Gas Pipelines - Iron (Excl Cast Iron) or Steel - Seamless	HS 730511 - Line Pipe (Circular) For Oil or Gas Pipelines - Longitudinally Submerged Arc Welded - Iron or Steel	HS 730512 - Line Pipe (Circular) For Oil or Gas Pipe-lines - Longitudinally Welded Nes - Iron or Steel	HS 730519 - Line Pipe (Circular) For Oil or Gas Pipelines - Other Nes - Iron or Steel	HS 730610 - Line Pipe For Oil or Gas Pipelines - Welded, Riveted or Closed Nes - Iron or Steel	
Carbon Capture Utilization & Storage (CCUS)	Low-Carbon Concrete	Hs 381600 - refractory cements, mortars, concretes and similar compositions, nes	HS 382340 - Prepared Additives For Cements, Mortars or Concretes	HS 382350 - Non-Refractory Mortars and Concretes	HS 382440 - Prepared Additives For Cements, Mortars or Concretes	HS 382450 - Non-Refractory Mortars and Concretes	HS 681091 - Pre-fabricated Structural Components For Buildings - of Cement, Concrete or Artificial Stone	HS 681099 - Articles Nes - of Cement, Concrete or Artificial Stone Nes	HS 847431 - Concrete or Mortar Mixers	HS 870540 - Concrete-Mixer Lorries (Trucks),
Carbon Capture Utilization & Storage (CCUS)	Direct Air Capture Technology	Hs 842139 - filtering or purifying machinery and apparatus - for gases nes	HS 842199 - Parts For Filtering or Purifying Machinery and Apparatus For Liquids or Gases,							
Carbon Capture Utilization & Storage (CCUS	Non-thermal use of fossil-based feedstocks	Hs 250410 - natural graphite - in powder or flakes	HS 250490 - Natural Graph-ite - Except in Powder or Flake	HS 271490 - Natural Bitumen and Asphalt; Asphaltites and Asphaltic Rocks	HS 271500 - Bituminous Mixtures Based On Asphalt, Bitumen or Mineral Tar/Tar Pitch	HS 282530 - Vanadium Oxide and Hydroxides	HS 380110 - Artificial Graphite	HS 390140 - Ethylene-alpha-olefin copolymers, having a specific gravity of less than 094	HS 390290 - Polymers of Propylene or of Other Olefins Nes - in Primary Forms	HS 390490 - Polymers of Other Halogenated Olefins, Nes - in Primary Forms
		HS 680790 - Asphalt or Similar Material Articles - Not in Rolls	HS 681510 - Non-Electrical Articles of Graphite or Other Carbon	HS 720292 - Ferro-Vanadium	HS 811240 - Vanadium and Articles Thereof, Including Waste, Scrap and Powders	HS 811292 - Gallium, Germanium, Hafnium, Indium, Niobium, Rhenium, Vanadium, Un-wrought; Waste & Scrap; Powder	HS 811299 - Gallium, Germanium, Hafnium, Indium, Niobium, Rhenium, Vanadium and Articles Thereof, Nes	HS 854511 - Carbon or Graphite Electrodes - For Furnaces	HS 854519 - Carbon or Graphite Electrodes - For Electrical Purposes, Nes	HS 854520 - Carbon or Graphite Brushes
		HS 680710 - Asphalt or Similar Material Articles - in Rolls	HS 854590 - Articles of Carbon or Graphite - For Electrical Purposes, Nes							

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Renewable Energy Generation	Energy Production / Integration	Hs 271600 - Electrical Energy	Biogas generator sets; Gas Generator (ex-85023900) [Ch]	Hs 841011 - Hydraulic Turbines And Water Wheels - Power Not Exceeding 1,000 Kw	Hs 841012 - Hydraulic Turbines And Water Wheels - Power 1,000-10,000 Kw	Hs 841013 - Hydraulic Turbines And Water Wheels - Power Exceeding 10,000 Kw	HS 841090 -Hydraulic turbines elsewhere specified and water wheels; parts, including regulators	Hs 850231 - Electric Generating Sets - Wind-Powered	Hs 854140 - Photosensitive Semiconductor Devices, Photo-voltaic Cells And Light Emitting Diodes	
Energy Storage	Energy Storage	Hs 850610 - Primary Cells And Batteries - Manganese Dioxide	Hs 850640 - Primary Cells And Batteries - Silver Oxide	Hs 850650 - Primary Cells And Batteries - Lithium	Hs 850660 - Primary Cells And Batteries - Air-Zinc	Hs 850611 - Primary Cells And Batteries - Manganese Dioxide - External Volume <301 Cm3	Hs 850612 - Primary Cells And Batteries - Mercuric Oxide - External Volume <301 Cm3	Hs 850613 - Primary Cells And Batteries - Silver Oxide - External Volume <301 Cm3	Hs 850619 - Primary Cells And Batteries - Other Chemical Nes - External Volume <301 Cm3	Hs 850620 - Primary Cells And Batteries - Chemi-cal - External Volume >300 Cm3
		Hs 850630 - Primary Cells And Batteries - Mercuric Oxide	Hs 850690 - Parts Of Primary Cells And Primary Batteries	HS 280519 - Alkali Metals (Other than Sodium and Calcium)	HS 282520 - Lithium Oxide and Hydroxides	HS 283691 - Lithium Carbonates	HS 290433 - Lithium perfluorooctane sulphonate, whether or not halogenated			
Hydrogen Economy	Hydrogen Production	HS 280410 - Hydrogen	HS 854330 - Machines and Apparatus For Electroplating, Electrolysis or Electrophoresis	HS 382479 - Other Mixtures Cntg Halogenated Derivatives of Methane,Ethane or Propane,Nes						
Hydrogen Economy	Hydrogen Transportation	HS 870390 - Motor Vehicles - Passenger Transport - Other Nes								
Hydrogen Economy	Hydrogen Use	Hs 850680 - Primary Cells And Batteries - Other Nes (Including Fuel Cells)								

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Bio-Products	Biochemicals	Hs 110811 - wheat starch	HS 110812 - Maize (Corn) Starch	HS 110813 - Potato Starch	HS 110814 - Manioc (Cassava) Starch	HS 110819 - Starch-es Nes	HS 110820 - Inulin	HS 292320 - Lecithins and Other Phosphoam-inolipids	HS 293311 - Phenazone (Antipyrin) and Its Derivatives	HS 293319 - Heterocyclic Compounds Containing An Unfused Pyrazole Ring in The Structure, Nes
		HS 293321 - Hydantoin and Its Derivatives	HS 293329 - Heterocyclic Compounds Containing An Unfused Imidazole Ring in The Structure, Nes	HS 293331 - Pyridine and Its Salts	HS 293332 - Piperidine and Its Salts	HS 293333 - Methylphendate (Inn), Similar Com-pounds and their Salts	HS 293339 - Heterocyclic Com-pounds Containing An Unfused Pyridine Ring in The Structure, Nes	HS 293340 - Heterocyclic Compounds Containing A Quinoline or Isoquinoline Ring System (Not Further Fused)	HS 293341 - Levorphanol (Inn) and Its Salts	HS 293349 - Other Heterocyclic Compounds Containing A Quinoline or Isoquinoline Ring System (Not Further Fused)
		HS 293351 - Malonylurea (Barbituric Acid) and Its Derivatives (Incl. Salts Thereof)	HS 293352 - Barbituric Acid and Its Salts	HS 293353 - Phenobarbitals (Inn) and Similar Compounds and their Salts	HS 293354 - Other Derivatives of Malonylurea (Barbituric Acid)	HS 293355 - Methaqualone (Inn), Lozprazolam (Inn), Mecloqualone (Inn), Zipeprol (Inn) and their Salts	HS 293359 - Heterocyclic Com-pounds Containing A Pyrimidine Ring or Piperazine Ring, Nes	HS 293361 - Melamine	HS 293369 - Heterocyclic Compounds Containing An Unfused Triazine Ring in The Structure, Nes	HS 293371 - 6-Hex-anelactam (Epsilon-Capro-lactam)
		HS 293372 - Clobabazam (Inn) and Methyprylon (Inn)	HS 293379 - Other Lactams Nes	HS 293390 - Heterocyclic Compounds With Nitrogen Hetero-Atom(S) Only Nes (Incl Benzodiaz-epenes)	HS 293391 - Diazepam (Inn), Flurazepam (Inn), Oxaze-pam (Inn), Chlorazepate and Other Benzodiaze-penes	HS 293392 - Azinphosmethyl	HS 293399 - Other Heterocyclic Com-pounds With Nitrogen Hetero-Atom(S) Only Nes	HS 293490 - Heterocy-clic Compounds Nes (Including Morpholine, Sultones, Sultams and Nucleic Acids)	HS 293499 - Other Heterocyclic Com-pounds Nes (Including Morpholine, Sultones, Sultams and Nucleic Acids)	HS 300210 - Antisera, Other Blood Fractions and Immunological Products
		HS 350220 - Milk Albumin, Including Concentrates of Two or More Whey Proteins	HS 391390 - Natural Polymers, Modified Natural Polymers Nes - in Primary Forms							

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Bio-Products	Bioplastics	Hs 390770 - poly(lactic acid), in primary forms								
Bio-Products	Bioplastics	Hs 300110 - glands and other organs, dried, pow-dered or not - for thera-peutic uses	HS 300120 - Extracts of Glands or Other Organs or of their Secretions - Therapeutic Uses	HS 300190 - Heparin & Its Salts;Human/ Animal Subs For Therap or Prophltc Uses, Nes	HS 300210 - Antisera, Other Blood Fractions and Immunological Products	HS 300211 - Malaria diag-nostic test kits	HS 300212 - Antisera & other blood fractions, whether or not modified/ obtained by biotechnologi-cal proc	HS 300213 - Immunological products, unmixed, not put up in measured doses/forms/ packings frs	HS 300214 - Immunological products,- mixed,not put in measured doses/forms/ packings f ret sale	
		HS 300215 - Immunological products, put up in measured dos-es/forms/ packings, for retail sale	HS 300219 - Immunological products, nes, whether or not modified/ obtained by biotechnologi-cal processes	HS 300220 - Vaccines - Human Uses	HS 300230 - Vaccines For Veterinary Medicine	HS 300231 - Vaccines Against Foot or Mouth Disease - Veterinary Uses	HS 300239 - Vaccines Nes - Veterinary Uses	HS 300290 - Other Human or Animal Blood Preparations Nes		
		HS 300310 - Medicaments (Bulk) With Penicillins, Streptomycins or their Derivatives	HS 300320 - Medicaments (Bulk) With Other Antibiotics Nes	HS 300331 - Medicaments (Bulk) Contain-ing Insulin	HS 300339 - Medicaments (Bulk) Containing Hormones But No Insulin or Contraceptives	HS 300340 - Medicaments (Bulk) Contain-ing Alkaloids But No Hormones or Antibiotics	HS 300341 - Medicaments,- cont ephedrin/ salts,mix,ther-ap/prophltc us-es,nfrs,	HS 300342 - Medicaments,- cont pseudo-ephed-rine/ sa,mix,therap/ prophltc,nfrs,		
		HS 300343 - Medica-ments,cont norephed-rine/ salts,mix,ther-ap/prophltc,nfrs	HS 300349 - Medicaments,- cont alkaloids/ deriv t/o,nes,- mix,f therap/ prophltc,nfrs	HS 300360 - Medicaments,- cont antimalari-al active princi-ples,mixed,nfrs	HS 300390 - Medicaments (Bulk) Nes	HS 300410 - Penicillins or Streptomycins and their Derivatives - in Dosage	HS 300420 - Antibiotics Nes - in Dosage	HS 300431 - Insulin - in Dosage		
		HS 300432 - Adrenal Cortical Hormones - in Dosage	HS 300439 - Hormones Nes Other than Antibiotics or Contraceptives - in Dosage	HS 300440 - Alkaloids or their Derivatives - Other than Antibiotics or Hormones - in Dosage	HS 300441 - Medicaments,- cont ephedrin/ salts,therap/ prophltc,in doses/frs	HS 300442 - Medi,cont pseudoephed-rine/salts,ther-ap/prophltc,in doses/frs	HS 300443 - Medi,cont norephed-rine/ salts,therap/ prophltc,in doses/frs	HS 300449 - Medi,cont alkaloids/deriv t/o,nes,therap/ prophltc,doses/ frs	HS 300450 - Vitamins and their Derivatives - in Dosage	HS 300460 - Medicaments,- cont anti-ma-larial active principles,in doses/frs
		HS 300490 - Medicaments Nes - in Dosage	391390 - Nat-ural Poly-mers, Modi-fied Nat-ural Polymers Nes - in Primary Forms	HS 391710 - Sausage Cas-ings (Artificial Guts) of Hard-ened Protein or of Cellulosic Materials						

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Bio-Products	Engineered Forest Products	Hs 441299 - veneered panels and similar laminated wood, nes,	Hs 440810 - veneer/ plywood sheets (thickness <6mm) - coniferous wood	HS 440820 - Veneer/ Plywood Sheets (Thickness <6Mm) - Tropical Wood	HS 440831 - Veneer/ Plywood Sheets (Thickness <6Mm) - (Meranti Red (Light and Dark) and Meranti Bakau)	HS 440839 - Veneer/ Plywood Sheets (Thickness <6Mm) - Tropical Wood Nes	HS 440890 - Veneer/ Plywood Sheets (Thickness <6Mm) - Other Wood Nes	HS 441012 - Oriented Strand Board (Osb), of Wood	HS 441019 - Waferboard and Similar Board, of Wood, Nes	
		HS 441021 - Particle Boards of Wood - Oriented Strand-boards/ Waferboards - Unworked, Sanded	HS 441029 - Particle Boards of Wood - Oriented Strand-boards/ Waferboards - Other Nes	HS 441031 - Particle Boards of Wood - Other than Oriented Strand-boards/ Waferboards - Unworked, Sanded		HS 441032 - Particle Boards of Wood - Covered With Mela-nine-Impregnated Paper	HS 441033 - Particle Boards of Wood - Covered With Decorative Plastic Laminates	HS 441039 - Particle Boards of Wood - Edge or Face Worked (Whether Painted or Not)	HS 441299 - Veneered Panels and Similar Laminated Wood, Nes, Ply HS 441890 - Builder'S Joinery and Carpentery, of Wood, Nes	
Bio-Products	Cellulose Nanofibers (CNF)	Hs 391211 - cel-lulose acetates, non-plasticized - in primary forms	HS 391231 - Carboxymethyl-cellulose and Its Salts- in Primary Forms	HS 391239 - Cellulose Ethers Nes - in Primary Forms	HS 391290 - Cellulose Derivatives Nes- in Primary Forms	HS 391390 - Natural Poly-mers, Modified Natural Poly-mers Nes - in Primary Forms				
Methane monitoring & abatement		HS 902620 Instruments and apparatus for measuring or checking pres-sure of liquids or gases, nesoi. [US]	HS 902680 Instruments and apparatus for measuring or checking other variables of liquids or gases, nesoi. [US]	HS 902690 Instruments and apparatus for measuring or checking the flow, level, pressure or oth-er variables of liquids or gases (for example, flow meters, level gauges, manometers, heat meters), excluding instruments and apparatus of heading 90.14, 90.15, 90.28 or 90.32 [Au]	Hs 902790 - Microtomes; Parts And Accessories Of Instruments And Apparatus For Physical Or Chemical Analysis	HS 300410 - Penicillins or Streptomycins and their Derivatives - in Dosage				

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Ag-tech		Hs 230990 - animal feed preparations nes (incl supplemented with antibiotics and/ vitamins)	HS 841931 - Non-Domestic Dryers - For Agricultural Products (Excl Tobacco and Processed Food Prod-ucts)	HS 843210 - Ploughs (For Agriculture, Horticulture or Forestry)	HS 843221 - Disc Harrows (For Agriculture, Horticulture or Forestry)	HS 843229 - Scarifiers, Cultivators, Weeders and Hoes (For Agriculture, Horticulture or Forestry)	HS 843231 - No-till direct seeders, planters and trans-planters,for agriculture/ hort/forestry	HS 843239 - Seeders, planters and transplanters, for agriculture/ horticulture/ forestry, nes	HS 843240 - Manure Spreaders and Fertilizer Distributors	HS 843241 - Manure spreaders, for agriculture/ horticulture/ forestry
		HS 843280 - Rollers, Stone-Removers and Other Soil Preparation or Cultivation Machinery	HS 843290 - Parts For Rollers and Other Soil Preparation or Cultivation Machinery	HS 843319 - Non-Powered Mowers - For Lawns, Parks or Sports Grounds - With Horizontal Cutting Device	HS 843320 - Other Mowers Nes (Including Cutter Bars For Tractor Mounting)	HS 843330 - Swathers, Windrowers and Other Hay-making Machinery	HS 843340 - Straw or Fodder Balers (Including Pick-Up Balers)	HS 843359 - Forage Harvesters and Other Harvesting Machinery Nes	HS 843610 - Machinery For Preparing Animal Feeding Stuffs	HS 843629 - Poultry-Keeping Machinery Nes
		HS 843242 - Fertilizer distributors, for agriculture/ horticulture/ forestry	HS 843680 - Other Agricul-tural, Horticul-tural, Forestry and Bee-Keep-ing Machinery Nes	HS 843880 - Other Machinery For The Industrial Preparation of Food and Bev-erages (Incl Fish Preparation)						
Small Modular Reactor		Hs 284450 - spent (irradiated) fuel elements (cartridges) of nuclear reactors	HS 840110 - Nuclear Reactors	HS 840140 - Parts of Nuclear Reactors						
Waste management and advanced recycling technologies		HS 840290 Parts for super-heated water boilers and steam or other vapour generation boilers (other than centra heating hot water boilers) [HK]	Hs 841780 - Non-Electric Furnaces And Ovens - Other Industrial Or Laboratory Nes (Incl Incinera-tors)	Hs 841790 - Parts Of Non-Electric Industrial Or Laboratory Furnaces And Ovens (Inc Incinerators)	HS 842220 - Machinery for cleaning or drying bottles or other containers	HS 842381 -Other weighing machinery having a maximum weighing capacity not exceeding 30 kg	HS 842382 -Other weighing machinery having a maximum weighing capacity exceeding 30kg but not exceeding 5,000 kg	HS 842389 -Other weighing machinery not elsewhere specified	Hs 846291 - Hydraulic Press-es - For Working Metal Or Metal Carbides	Hs 847290 - Office Machines, Nes

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Waste management and advanced recycling technologies		Hs 847989 - Machines & Mechanical Appliances, Having Individual Functions, Nes	Hs 847990 - Parts Of Ma-chines & Mechanical Appliances, Having Individual Functions, Nes	Hs 850590 - Electromagnets; Other, Including Parts	Hs 851410 - Industrial And Laboratory Electric Resistance Heated Furnaces And Ovens	Hs 851420 - Indus-trial And Laboratory Electric Induction Or Dielectric Furnaces And Ovens	Hs 851490 - Parts Of Industrial Or Laboratory Electric Furnaces And Ovens Nes	HS 854330 - Machines elsewhere specified & apparatus for electroplating, electrolysis or electrophoresis	HS 901320 - Lasers, other than laser diodes	
Water efficiency and wastewater treatment technologies		Hs 392690 - Articles Of Plastics, Nes & Art Of Other Mate-rials Of Hds 39.01 To 39.14, Nes	Hs 460120 - Mats, Matting And Screens Of Vegetable Plaiting Materials	Hs 560314 - Nonwovens - Man-Made Filaments - Weighing More Than 150G/M2	Hs 730900 - Reservoirs, Tanks, Vats & Sim Ctnr, Cap >300L,I O S (Ex Liq/Compr Gas Type)	Hs 731010 - Tanks, Casks, Drums, Cans, Boxes And Similar Containers, Of Iron Or Steel, For Any Material, Of A Capacity Of >= 50 L But =< 300 L, Not Elsewhere Specified (Excl. Containers For Compressed Or Liquefied Gas , Or Containers Fitted With Mechanical Or Thermal Equipment, Products)	Hs 731029 - Tanks, Casks, Drums, Cans, Boxes And Similar Containers, Of Iron Or Steel, For Any Material, Of A Capacity Of < 50 L, Not Elsewhere Specified	Hs 841320 - Hand Pumps Not Elsewhere Specified	Hs 841350 - Reciprocating Positive Dis-placement Pumps Not Elsewhere Specified	HS 854390 Parts for 854389x. [Ca, Ja, NZ, K, CT, Au]
		HS 840290 Parts for super-heated water boilers and steam or other vapour generation boilers (other than centra heating hot water boilers) [HK]	Hs 841780 - Non-Electric Furnaces And Ovens - Other Industrial Or Laboratory Nes (Incl Incinera-tors)	Hs 841790 - Parts Of Non-Electric Industrial Or Laboratory Furnaces And Ovens (Inc Incinerators)	HS 842220 - Machinery for cleaning or drying bottles or other containers	HS 842381 -Other weighing machinery having a maximum weighing capacity not exceeding 30 kg	HS 842382 -Other weighing machinery having a maximum weighing capacity exceeding 30kg but not exceeding 5,000 kg	HS 842389 -Other weighing machinery not elsewhere specified	Hs 846291 - Hydraulic Press-es - For Working Metal Or Metal Carbides	Hs 847290 - Office Machines, Nes

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Water efficiency and wastewater treatment technologies		HS 842121 Water filter-ing or purify-ing [M] machinery and appa-ratus. [US, BD]	HS 847982 Waste sorting, screening, crushing, grinding, shredding, washing and compacting devices. Agita-tor for wastewater treatment; flash mixer and flocculator. [Au]							
Digitalization		HS 901540 - Photogramme-terical surveying instruments and appliances	HS 901580 -Other instru-ments and appliances used in geodesy, topography, hydrography, oceanography, hydrology, meteorology or geophysics	HS 901590 - Parts and acces-sories for instruments and appliances used in geodesy, topography, photogrammet-rical surveying, hydrography, oceanography, hydrology, meteorology or geophysics, and for rangefinders not elsewhere specified	HS 902229 Apparatus based on the use of alpha, beta, or gamma radiations, for other uses	Hs 902590 - Parts And Accessories For Use With Measuring Apparatus	Hs 902610 - Instruments And Apparatus For Measuring Or Checking The Flow Or Level Of Liquids	Hs 902710 - Gas Or Smoke Analysis Apparatus	Hs 902720 - Chromato-graphs And Electrophoresis Instruments	
		Hs 902730 - Spectrometers, Spectropho-tometers And Spectrographs Using Optical Radiations (Uv, Visible, Ir)	Hs 902740 - Exposure Me-ters (Photoeters)	Hs 902780 - Instruments And Apparatus For Physical Or Chemical Analysis, Nes	Hs 903020 - Oscilloscopes And Oscillographs	Hs 903031 - Multimeters	HS 382200 - Composite diagnostic or laboratory reagents, not elsewhere specified	HS 903149 Other optical instruments, appliances and machines elsewhere specified for measuring or checking	HS 903180 Other measur-ing or checking instruments, appliances and machines	HS 903190 - Parts and accessories (for nominated articles of sub-heading 9031)
		HS 903210 Thermostats	HS 903220 Manostats							

Table 5: HS Commodity Codes by Clean Technology Subsector

Sub-sector	Segment	HS Commodity Codes								
Electrification and grid infrastructure		HS 903039 Other instruments and apparatus, for measuring or checking voltage, current, resistance or power, without a recording device	HS 903083 - Other instruments and apparatus for measuring or checking electrical quantities, with a recording device	HS 903089 Other instruments and apparatus for measuring or checking electrical quantities	HS 903090 Parts and accessories (for nominated articles of subheading 9030)	HS 903281 Hydraulic and pneumatic instruments and apparatus	HS 903289 Automatic regulating or controlling instruments, other	HS 903290 Parts and accessories - automatic regulating or controlling instruments	HS 903300 - Parts and accessories (not specified or included elsewhere in this Chapter)	Hs 850421 - Liquid Dielectric Transformers - Power Handling Capacity Not Exceeding 650 Kva
		Hs 850422 - Liquid Dielectric Trans-formers - Power Handling Capacity 651-10,000 Kva	Hs 850423 - Liquid Dielectric Transformers - Power Handling Capacity Exceeding 10,000 Kva	Hs 850431 - Electric Trans-formers Nes - Power Handling Capacity Not Exceeding 1 Kva	Hs 850432 - Electric Trans-formers Nes - Power Handling Capacity 2-16 Kva	Hs 850433 - Electric Transformers Nes - Power Handling Capacity 17-500 Kva	Hs 850434 - Electric Transformers Nes - Power Handling Capacity Exceeding 500 Kva	Hs 850490 - Parts Of Electrical Transformers, Static Converters And Inductors	Hs 853710 - Boards And Panels (Including Numerical Control Panels) - For Voltage Not Exceeding 1,000 V	Hs 853720 - Boards And Panels (Including Numerical Control Panels) - For Voltage Exceeding 1,000 V
		Hs 853590 - Other Apparatus Nes - For Switching, Protecting Or Connecting Electric Circuits - Exceeding 1,000 V	Hs 853690 - Other Apparatus - For Switching, Protecting Or Connecting Electric Circuits - Not Exceeding 1,000 V	Hs 860110 - rail locomotives - powered by external electrical source	HS 860120 - Rail Locomotives - Powered By Batteries (Accumulators)	HS 860310 - Self-Propelled Railway Cars - Powered By External Electrical Source	HS 870290 - Bus-es/Public Transport Passenger Vehicles - Other Nes	HS 870390 - Motor Vehicles - Passenger Transport - Other Nes	HS 871160 - Motorcycles, with electric motor	
Sustainable transportation fuel	Aviation fuels	Hs 271012 - light oils and preparations								
	Renewable natural gas	Hs 271129 - petroleum or hydrocarbon gases in gaseous state (excluding natural gas)								
Sustainable fuel development	Biofuels	Hs 220710 - undenatured ethyl alcohol - alcohol strength 80per cent or higher	HS 271020 - Petroleum Oils and Oils Obtained from Bituminous Minerals, Containing By Weight 70per cent or More of Oils	HS 290511 - Methanol (Methyl Alcohol)	HS 382600 - Biodiesel and Mixtures	HS 440131 - Saw-dust, Wood Waste and Scrap W/E or Not Agglomerated in Logs, Briquettes, Pellets: Wood Pellets				

Table 5: HS Commodity Codes by Clean Technology Subsector

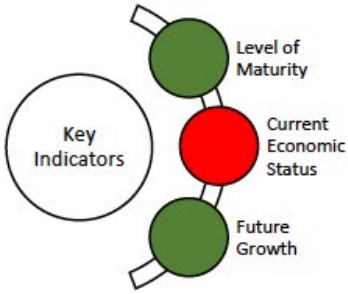
Sub-sector	Segment	HS Commodity Codes								
Energy efficiency	High-performance HVAC	Hs 841581 - Air Conditioning Machines (Air Conditioners) - With Valve For Reversal Of Cooling/Heat Cycle	Hs 841582 - Air Conditioning Machines (Air Conditioners) - Incorporating A Refrigerating Unit	Hs 841520 - Air Conditioning Machines (Air Conditioners) - Of A Kind Used For Persons In Motor Vehicles	Hs 732190 - Parts For Non-Electric Heating Appliances	Hs 840390 - Parts For Central Heating Boilers (Other Than Steam Or Other Vapour Generating Boilers)	Hs 841510 - Air Conditioning Machines (Air Conditioners) - Window Or Wall Types, Self-Contained	Hs 841459 - Room, Table, Floor, Wall, Window, Ceiling Or Roof Fans - Motor With Output Exceeding 125W		
		Hs 732181 - Other Non-Electric Appliances Nes (Incl Boilers) - Gas Or Combination Fuels - Iron Or Steel	Hs 841583 - Air Conditioning Machines (Air Conditioners) - Not Incorporating A Refrigerating Unit	Hs 732219 - Non-Electric Radiators And Parts Thereof - Iron (Excl Cast Iron) Or Steel	Hs 841590 - Parts Of Air Conditioning Machines (Air Conditioners)	Hs 841451 - Room, Table, Floor, Wall, Window, Ceiling Or Roof Fans - Motor With Output 125W Or Less	HS 841919 Other instantaneous or storage water heaters, nonelectric			
Energy efficiency	Co-generation	Hs 732182 - Other Non-Electric Appliances Nes (Incl Boilers) - Liquid Fuels - Iron Or Steel	HS 841950 Heat exchange units	Hs 840310 - Central Heating Boilers (Other Than Steam Or Other Vapour Generating Boilers)	Hs 732290 - Non-Electric Air Heaters, Hot Air Distributors And Similar Appliances Nes - Iron Or Steel	Hs 732211 - Non-Electric Radiators And Parts Thereof - Cast Iron				

APPENDIX C

Ag-tech

Includes technologies that reduce the environmental impact or improve the efficiency of farming and agriculture operations.

Alberta is a leading global and national exporter in agriculture, as well as a champion in artificial intelligence and machine learning research. Ag-tech provides an opportunity to combine one of Alberta's top-performing economic industries – agriculture – with an emerging cleantech expertise area. Ag-tech will be pivotal to reaching global decarbonisation goals, through nature-based emission reductions, carbon off-sets and the carbon marketplace. Alberta's agribusiness sector is forecast to invest $246 million in digital transformation by 2024. Ag-tech itself is forecast to become a $730 billion (USD) industry worldwide by 2023, creating a strong market opportunity for Alberta.

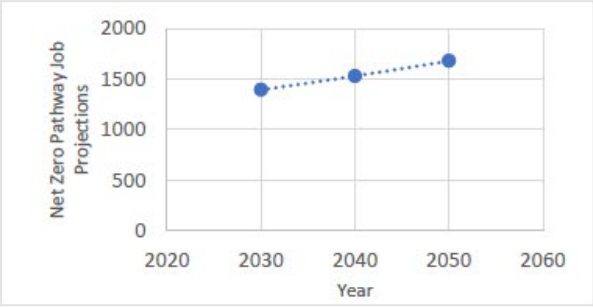


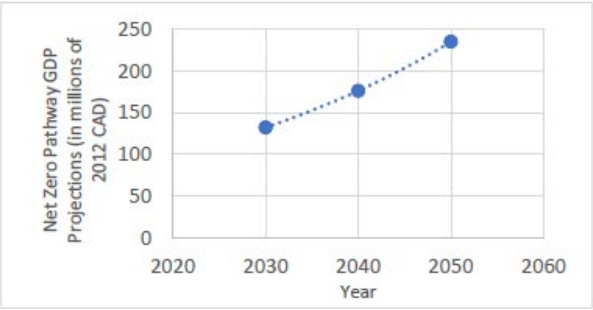
2020 Economic Contributions from Ag-tech in Alberta

1,270 people	$99 million	$101 million	3%
2020 Employment	**2020 GDP**	**2020 Exports**	**Net Zero Pathway CAGR**

Source: Delphi Group Economic Model

Net Zero Pathway Projections[1]





Source: Delphi Group Economic Model

Emerging technology verticals within the ag-tech sector include:

- Precision farming
- Vertical farming
- Smart irrigation systems

Ag-tech companies in Alberta are on the leading edge of the sector. These companies include:

- Decisive Farming[i]
- Future Fields[ii]
- GranDuke Geomatics[iii]
- Livestock Water Recycling[iv]
- Symbiotic EnviroTek Inc[v]
- The HarvestHub[vi]

Alongside businesses, organizations and institutions in Alberta are helping the innovation of ag-tech, including:

- Canadian Agri-Food Automation and Intelligence Network (CAAIN)[vii]
- Canadian Beef Centre of Excellence[viii]
- Food Processing Development Centre[ix]
- Olds College[x]
- Protein Industries Canada[xi]
- University of Alberta[xii]
- University of Lethbridge[xiii]

Some recent investors in Alberta's ag-tech ecosystem include:

- Dairy Farmers of America[xiv]
- McRock Capital[xv]
- Bee Partners[xvi]

[1] These figures represent the expected employment and GDP growth in the sector if Alberta reaches a net zero economy by 2050.

The companies in this cleantech sector are well-established and have received patents for their products. The sector's job creation has been growing, though current economic status could be improved with increased exports. Future growth and opportunities look promising with research, innovation, and further deployment in Alberta's agricultural heartland.

Programs and Policy Drivers

Agricultural Clean Technology Programme[xvii] supports investments made by provincial and territorial governments and industry stakeholders in research, development, and adoption of clean technologies for the agriculture, agri-food and agriculture-based products sector, specifically precision agriculture, and bio-based products from agriculture.

The Canadian Agricultural Strategic Priorities Program (CASPP)[xviii] is a five-year investment that focuses on four priority areas: adoption of new technology, environmental sustainability, strategic development and capacity building, and emerging issues.

SVG Ventures|THRIVE, a leading global agrifood venture and innovation platform, and Farm Credit Canada launched the SVG THRIVE Canada Challenge[xix] in 2020 to bolster innovation and development in Canada's Ag-tech sector. In June 2021, SVG Ventures|THRIVE, announced the establishment of THRIVE Canada, their Canadian subsidiary, which will be headquartered in Calgary.

The Canadian Agricultural Partnership[xx] is a five-year federal investment to strengthen and grow Canada's agriculture and agri-food sector.

The Smart Agriculture and Food Digitization and Automation Challenge[xxi] through Alberta Innovates aims to develop technologies or generate knowledge related to smart agriculture.

The Pan-Canadian Smart Farm Network Development[xxii] brings together post-secondary educational institutes and industry partners to support the development of smart farms through research, demonstration, and training opportunities in post secondary agricultural programs

Key Indicator Methodology

Level of Maturity – indicated by the age of cleantech companies operating in the space, as well as the age of policies and regulations. Red – low maturity (policies, companies 1-5 years old); Yellow – moderate maturity (policies, companies 5-10 years old); Green – high maturity (policies, companies 10+ years old).

Current Economic Status – indicated by the subsector market size measured in GDP of 2012 dollars. Red – small market size (GDP of $10 million-$100 million); Yellow – medium market size (GDP of $100-$300 million); Green – large market size (GDP of $300 million or more).

Future Growth – indicated by net zero pathway CAGR, future job and GDP creation, future deployment potential and ability to capitalize on existing infrastructure and expertise. Red – low projected growth and economic impact; Yellow – moderate projected growth and economic impact; Green – high projected growth and potential impact.

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[i] http://www.decisivefarming.com/
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[iv] https://www.livestockwaterrecycling.com
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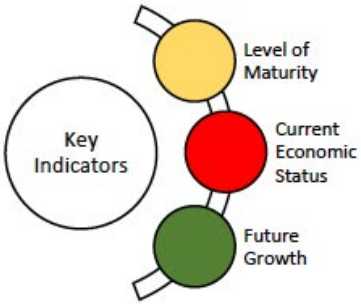
[xxii] https://www.oldscollege.ca/olds-college-smart-farm/pan-canadian-smart-farm-network/index.html

Carbon Capture, Utilization, and Storage (CCUS)

Includes technologies that capture, use or store carbon dioxide emissions.

Alberta's CCUS market is well-poised to support viable and profitable projects, as both demand and supply for such projects are strong. Alberta has world class large-scale CCUS infrastructure assets, such as the Alberta Carbon Trunk Line (ACTL), with a long and proven track record in all aspects of CCS, including drilling, injection, storage, monitoring and closure/capping. Additionally, Alberta has a high concentration of facilities around the Industrial Heartland and Fort McMurray that would provide a strong local market for CCUS technologies. There is also an emerging ecosystem of companies developing CO_2-derived products within Alberta.

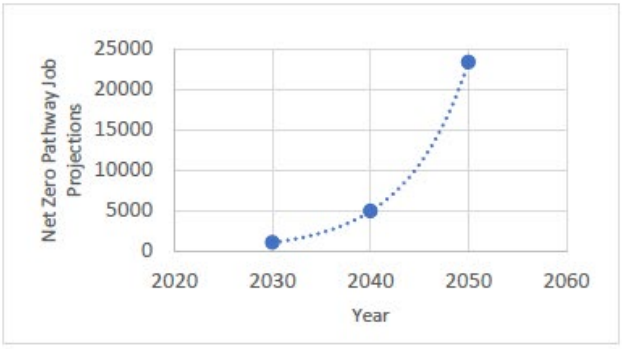


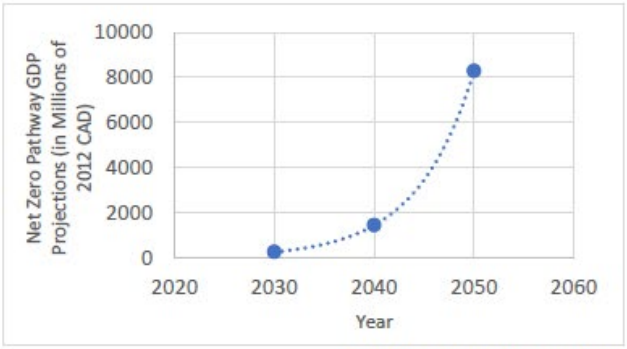
2020 Economic Contribution from CCUS in Alberta

220 people	$44 million	$110 million	19%
2020 Employment	**2020 GDP**	**2020 Exports**	**Net Zero Pathway CAGR**

Source: Delphi Group Economic Model

Net Zero Pathway Projections[1]





Source: Delphi Group Economic Model

Emerging technology verticals within CCUS include:

- Carbon sequestration technologies and infrastructure
- Direct air capture
- Low-carbon concrete

CCUS companies in Alberta are on the leading edge of the sector. These companies include:

- Carbon Upcycling Technologies[i]
- Carbonova Corp.[ii]
- CleanO2 Carbon Capture Technologies[iii]
- Industrial Climate Solutions[iv]
- See O2 Energy[v]
- Wolf Carbon Solutions (Carbon business unit of Wolf Mid-stream)[vi]

Alongside businesses, organizations in Alberta are helping the innovation of CCUS, including:

- Shell[vii]
- Canadian Technology Accelerator[viii]
- Enhance Energy[ix]
- Techstars Energy Accelerator[x]

Some recent investors in Alberta's CCUS ecosystem include:

- Alberta Cleantech Investment Summit[xi]
- Natural Gas Innovation Fund[xii]
- Sustainable Technology Development Canada[xiii]
- Creative Destruction Lab[xiv]

[1] These figures represent the expected employment and GDP growth in the sector if Alberta reaches a net zero economy by 2050.

CCUS is an emerging sector in Alberta, with maturing companies and an established ecosystem and infrastructure network. This is an area where Alberta is developing niche talent and experience. The sector's job creation has been vast, and the market size is large. Future growth looks promising with research, innovation, and further deployment in Alberta's Oil Sands refineries

Programs and Policy Drivers

Alberta-Canada CCUS Steering Committee[xv] is a federal and provincial collaboration to support the advancement Alberta's CCUS technologies and attract project investment.

The federal government has announced a new investment tax credit[xvi] starting in 2022, to support CCUS research and development, and will be available for a broad range of CCUS applications across different industrial subsectors (e.g., concrete, plastics, fuels).

Alberta's new carbon sequestration rights[xvii] will employ a competitive process for securing sub-surface rights to underground freehold and Crown pore space for the establishment of carbon hubs.

Key Indicators Methodology

Level of Maturity – indicated by the age of cleantech companies operating in the space, as well as the age of policies and regulations. Red – low maturity (policies, companies 1-5 years old); Yellow – moderate maturity (policies, companies 5-10 years old); Green – high maturity (policies, companies 10+ years old).

Current Economic Status – indicated by the subsector market size measured in GDP of 2012 dollars. Red – small market size (GDP of $10 million-$100 million); Yellow – medium market size (GDP of $100-$300 million); Green – large market size (GDP of $300 million or more).

Future Growth – indicated by net zero pathway CAGR, future job and GDP creation, future deployment potential and ability to capitalize on existing infrastructure and expertise. Red – low projected growth and economic impact; Yellow – moderate projected growth and economic impact; Green – high projected growth and potential impact.

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[i] https://www.carbonupcycling.com
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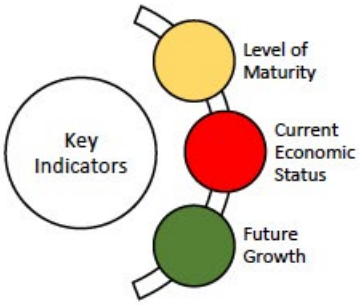
[xvii] https://inform.energy.gov.ab.ca/Documents/Published/IL-2021-19.pdf

Digitalization

Includes digital technologies that increase the digital capacity and efficiency of various sub-sectors thus contributing to the reduction of environmental impact.

Alberta is at the forefront of artificial intelligence (AI) and Machine Learning (ML) research. Alberta is home to the University of Alberta which is one of the top 3 AI research institutes globally and the Alberta Machine Intelligence Institute (AMII), which is 1 of only 3 of national AI hubs in Canada. The digitalization ecosystem is thriving on the unique synergy between Edmonton's AI research prowess and Calgary's entrepreneurial drive. Digitalization will be a key cross-cutting sector across financial services, healthcare, energy, agriculture and advanced manufacturing, and will be a key driver to employment growth in the coming decades. Alberta's bread-and-butter industries, including energy, agriculture and forestry, will be strong first-customers for locally developed digital technology. Locally developed technologies will also be able to avail of strong export market opportunities, given the universal application of many digital services and solutions.

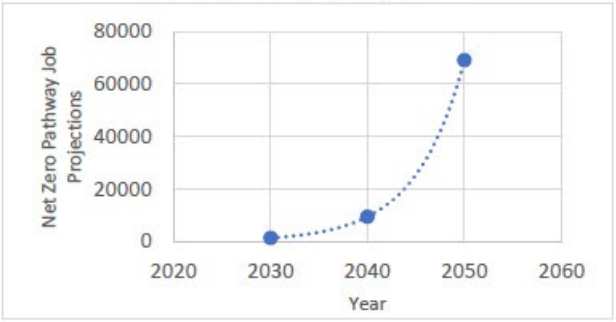


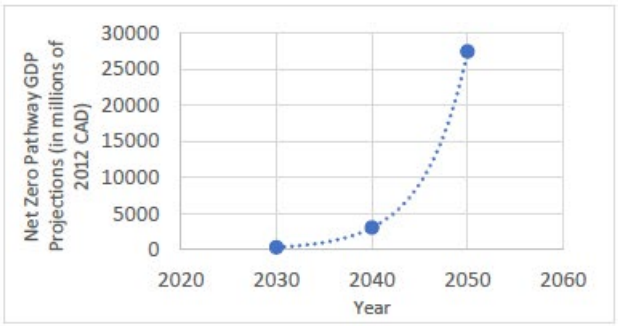
2020 Economic Contribution from Digitalization in Alberta

174 people	$38 million	$247 million	24%
2020 Employment	**2020 GDP**	**2020 Exports**	**Net Zero Pathway CAGR**

Source: Delphi Group Economic Model

Net Zero Pathway Projections[1]





Source: Delphi Group Economic Model

Emerging technology verticals within the digitalization sector include:

- Internet of Things (IoT) and sensors
- Data management and analytics
- Artificial intelligence and machine learning
- Augmented reality, virtual reality and digital twins

Digitalization companies in Alberta are on the leading edge of the sector. These companies include:

- Attabotics[i]
- Enersoft[ii]
- Jobber[iii]
- NTwist[iv]
- mcThings[v]
- SensorUp[vi]
- Veerum[vii]

Alongside businesses, organizations in Alberta are helping the digitalization ecosystem including:

- Alberta Machine Intelligence Institute[viii]
- Alberta Artificial Intelligence Association[ix]
- Exergy Solutions[x]
- Southern Alberta Institute of Technology (SAIT) School for Advanced Digital Technology[xi]
- University of Alberta[xii]
- Technology Alberta[xiii]
- Edmonton.AI[xiv]

[1] These figures represent the expected employment and GDP growth in the sector if Alberta reaches a net zero economy by 2050.

- AltaML Inc.[xv]

Some recent investors in Alberta's digitalization ecosystem include:

- Opportunity Calgary Investment Fund[xvi]
- McRock Capital[xvii]
- Western Innovation Initiative[xviii]
- GreenSky Capital[xix]
- Honeywell Venture[xx]

The companies in this cleantech sector are well-established, with some companies like Mobiltex Data having been in business since 1985. Alberta's support ecosystem and expertise in digital technologies, particularly in the research and development space, is quite mature. The level of deployment of solutions remains low in some areas like AI, ML and augmented reality. This is likely due to the fact that many businesses struggle to adapt their internal policies and regulations to allow for these emerging pathways. Strong leadership and innovative policy in the area of data management, data security and privacy will be needed to allow these solutions to deploy. The sector's job creation has been slow to date, and the market size is relatively small. Future growth looks promising as Alberta prioritizes digital job training and education programs, and heavy industry looks to digital solutions to modernize and strengthen the way they do business.

Programs and Policy Drivers

The government of Canada's Pan-Canadian Artificial Intelligence Strategy[xxi] is the world's first national AI strategy which invested $125M to foster growth in Canada's AI ecosystem. The 2021 federal budget commits to renew the strategy with a $443.8 million commitment over 10 years starting in 2021-22.

Scale AI Superclusters[xxii] is a federal government initiative that provides funding to accelerators and incubators to support the growth of AI start-ups and SMEs across Canada.

Key Indicators Methodology

Level of Maturity – indicated by the age of cleantech companies operating in the space, as well as the age of policies and regulations. Red – low maturity (policies, companies 1-5 years old); Yellow – moderate maturity (policies, companies 5-10 years old); Green – high maturity (policies, companies 10+ years old).

Current Economic Status – indicated by the subsector market size measured in GDP of 2012 dollars. Red – small market size (GDP of $10 million-$100 million); Yellow – medium market size (GDP of $100-$300 million); Green – large market size (GDP of $300 million or more).

Future Growth – indicated by net zero pathway CAGR, future job and GDP creation. Red – low projected growth and economic impact; Yellow – moderate projected growth and economic impact; Green – high projected growth and potential impact.

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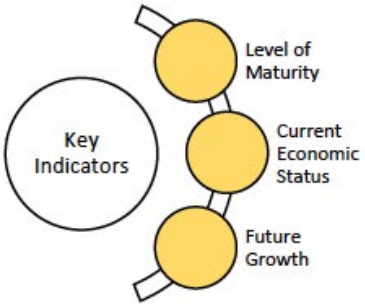
Electrification

Includes technologies such as software and hardware to control and manage electric vehicle (EV) charging and provide grid services, including demand response and vehicle-to-grid (V2G) services. This sector also includes electrification of heavy industry equipment and processes.

Alberta has a deregulated electricity market, which offers an advantageous structure for companies looking to develop and pilot electrification technologies. Alberta has the potential to be a leader in the development of transformational electrification technologies for heavy industry, such as radio frequency heating for bitumen extraction. Alberta's Industrial Heartland offers a strong local market for emerging industrial electrification solutions. The electrification sector in Alberta is also heavily integrated with key cleantech pathways needed to achieve a net-zero pathway, including energy storage, renewable energy generation and the deployment of small modular nuclear reactors (SMRs).

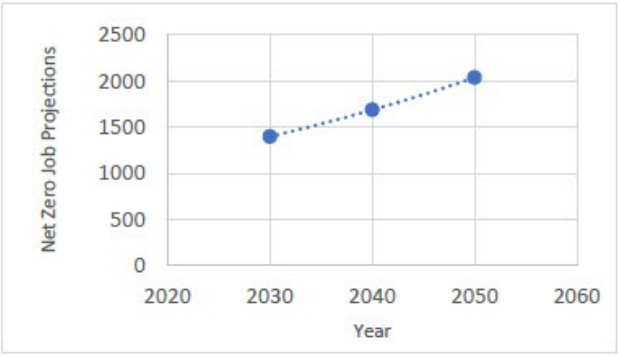


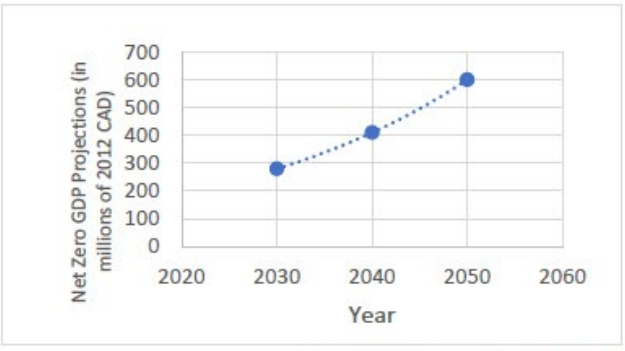
2020 Economic Contribution for Electrification in Alberta

1,157 people	$191 million	$140 million	4%
2020 Employment	**2020 GDP**	**2020 Exports**	**Net Zero Pathway CAGR**

Source: Delphi Group Economic Model

Net Zero Pathway Projections[1]





Source: Delphi Group Economic Model

Emerging technology verticals within the electrification sector include:

- Electrical grid infrastructure and resiliency
- Smart grid enhancement
- EV charging
- Rail line electrification

Electrification companies in Alberta are on the leading edge of the sector. These companies include:

- ASAT Solutions[i]
- DrishyaAI[ii]
- dTechs[iii]
- GSS Integrated Energy[iv]
- RUNWITHIT Synthetics[v]
- TerranTek[vi]

Alongside businesses, organizations in Alberta are helping the electrification ecosystem including:

- University of Alberta Smart Grid Lab[vii]
- University of Calgary[viii]
- NAIT's Centre for Grid Innovation [ix]
- Transition Accelerator[x]
- Electric Vehicle Association Alberta[xi]

Some recent investors in Alberta's electrification ecosystem include:

- Creative Destruction Lab[xii]
- The51 Ventures[xiii]

[1] These figures represent the expected employment and GDP growth in the sector if Alberta reaches a net zero economy by 2050.

The sector's job creation has been significant and market size and exports are both sizable as well. Future growth looks moderate over the long term as a standalone sub-sector but taking into consideration the strong ties electrification has to other cleantech pathways, its impact becomes even higher. When it comes to electrification in Alberta, it is important to understand its linkage with strong renewable energy potential – in the form of solar, wind and geothermal energy – that exists within the province. In order for electrification to become a viable net-zero pathway for Alberta the renewable energy share (currently ~10%[xiv]) of Alberta's grid must improve significantly.

Programs and Policy Drivers

Government of Canada's Zero Emission Vehicle Infrastructure Program (ZEVIP)[xv] is a five year 280 million program making EV infrastructure more accessible across Canada.

Natural Resources Canada's Smart Grid Program[xvi] provides $100M over four years on demonstration and deployment projects, to accelerate the development of smart grids.

Electric Vehicle Charging Program[xvii] is a municipalities-oriented program that seeks to offset the cost of installing charging stations for municipal vehicle fleet.

Both City of Calgary's Climate Resilience Strategy[xviii] and the City of Edmonton's Energy Transition Strategy[xix], calls for increased EV adoption to meet each respective City's climate and economic development goals.

Peak to Prairies EV Charging network[xx] is a regional initiative to create a robust electric vehicle charging corridor throughout southern Alberta.

Key Indicators Methodology

Level of Maturity – indicated by the age of cleantech companies operating in the space, as well as the age of policies and regulations. Red – low maturity (policies, companies 1-5 years old); Yellow – moderate maturity (policies, companies 5-10 years old); Green – high maturity (policies, companies 10+ years old).

Current Economic Status – indicated by the subsector market size measured in GDP of 2012 dollars. Red – small market size (GDP of $10 million-$100 million); Yellow – medium market size (GDP of $100-$300 million); Green – large market size (GDP of $300 million or more).

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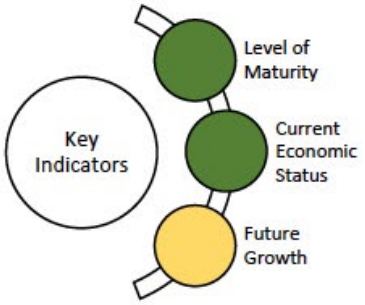
[xx] https://peakstoprairies.ca/

Energy Efficiency

Includes technologies utilized to improve operational and energy efficiency of commercial and industrial buildings, as well as residential properties. This sector also includes co-generation facilities.

Alberta is home to the largest cogeneration facilities in Canada with a proven track record of over 20 years supporting its electricity system. It also has the most competitive HVAC market among the provinces. Affordable energy prices and a deregulated electricity market make Alberta a promising investment location for industrial process energy efficiency and low carbon heat recovery technologies. Alberta has developed expertise in large-scale waste heat recovery, which may offer considerable export opportunities to regions looking to develop similar projects.

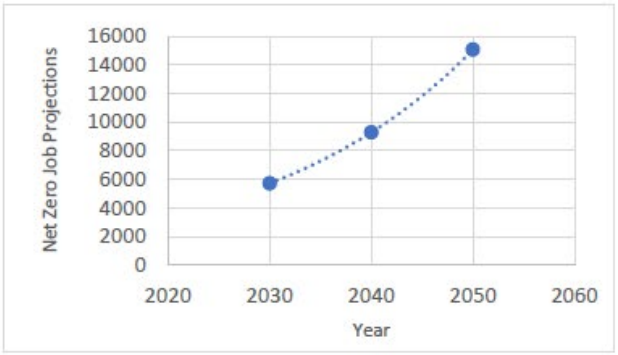


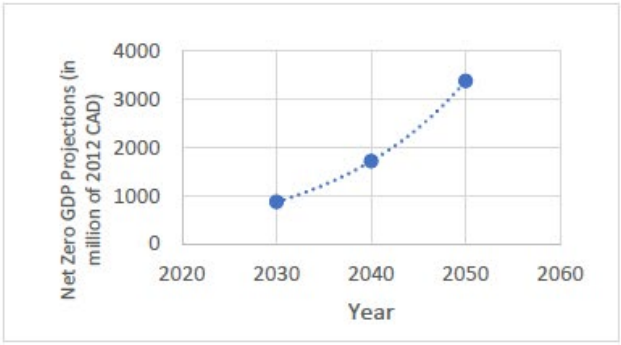
2020 Economic Contribution from Energy Efficiency in Alberta

3,524 people	$442 million	$401 million	7%
2020 Employment	**2020 GDP**	**2020 Exports**	**Net Zero Pathway CAGR**

Source: Delphi Group Economic Model

Net Zero Pathway Projections[1]





Source: Delphi Group Economic Model

Emerging technology verticals within the energy efficiency sector include:

- Waste heat recovery – including co-generation and low-grade heat recovery
- Energy management software and smart metering
- High-performance HVAC equipment

Energy efficiency companies in Alberta are on the leading edge of the sector. These companies include:

- Imperial[i]
- Suncor[ii]
- ATCO[iii]
- Co-genergy[iv]
- DES Engineering[v]
- eDecisions[vi]
- Advantage Cogen Energy[vii]
- GreyJay Energy[viii]
- Zeet Inc[ix]

Alongside businesses, organizations in Alberta are helping the energy efficiency ecosystem including:

- Alberta Energy Efficiency Alliance[x]
- Energy Futures Lab[xi]
- PACEAlberta[xii]
- The Municipal Climate Change Action Centre[xiii]

Some recent investors in Alberta's energy efficiency ecosystem include:

- Emission Reduction Alberta [xiv]

[1] These figures represent the expected employment and GDP growth in the sector if Alberta reaches a net zero economy by 2050.

Major companies like Imperial Oil and ATCO are doing their own development and deployment of co-generation technologies. The sector's job creation has been significant and the market potential and export earnings are both sizable as well. Future growth looks promising with the deployment of additional co-generation projects at commercial scale and the deployment of energy efficiency technologies within residential units, commercial buildings and industrial facilities. Stronger provincial policies, promoting the importance of energy efficiency in achieving a net-zero pathway, are needed to drive activity in this space, as well as incentives and programs that promote energy efficient technologies to residential, commercial and industrial customers. The closure of the provincial energy efficiency agency in the province, Energy Efficiency Alberta, is sending mixed signals to technology developers and investors in this space.

Programs and Policy Drivers

Energy Savings for Business[xv] offers fast access to incentives for cost-effective efficiency measures for up to $250,000 is available per project and up to $500,000 per parent company is available to cover the cost of products and services. ERA has also offered energy efficiency-specific funding programs, such as the Industrial Energy Efficiency Challenge[xvi].

Clean Energy Improvement Program (CIEP)[xvii] is a Property Assessed Clean Energy style program that enables building owners and developers to finance energy efficient upgrades to their buildings through property tax bill.

Edmonton's Building Energy Retrofit Accelerator[xviii] provides rebates and incentives for homeowners and developers to install energy efficient systems in commercial and institutional buildings.

Key Indicators Methodology

Level of Maturity – indicated by the age of cleantech companies operating in the space, as well as the age of policies and regulations. Red – low maturity (policies, companies 1-5 years old); Yellow – moderate maturity (policies, companies 5-10 years old); Green – high maturity (policies, companies 10+ years old).

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Future Growth – indicated by net zero pathway CAGR, future job and GDP creation, future deployment potential and ability to capitalize on existing infrastructure and expertise. Red – low projected growth and economic impact; Yellow – moderate projected growth and economic impact; Green – high projected growth and potential impact.

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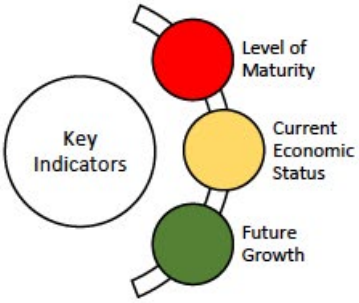
Hydrogen Production and Utilization

Includes the production of hydrogen with technology platforms which can utilize renewable or fossil fuels with (carbon capture) as a feedstock. Also includes technologies to create hydrogen fuel cells and material development.

Alberta is at the leading edge of hydrogen economy development in Canada. Home to Canada's first industrial hydrogen hub, it has all the required components to establish and expand its hydrogen economy – unique geology, well-established transportation infrastructure, proven track record in CCUS technology coupled with federal and provincial level strategies. With growing hydrogen demand worldwide, and two large scale industrial hydrogen projects (Suncor-ATCO hydrogen facility in Fort Saskatchewan and Air Products hydrogen complex) in progress, Alberta has an opportunity to be a global hydrogen leader in the coming decades. There is also a potential to tap into the Edmonton region's transportation corridor and heavy industry hub as an opportunity for local market uptake.

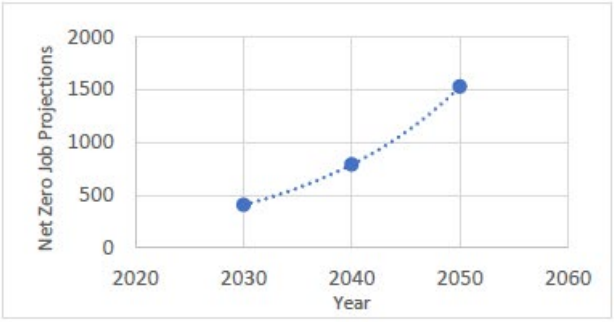


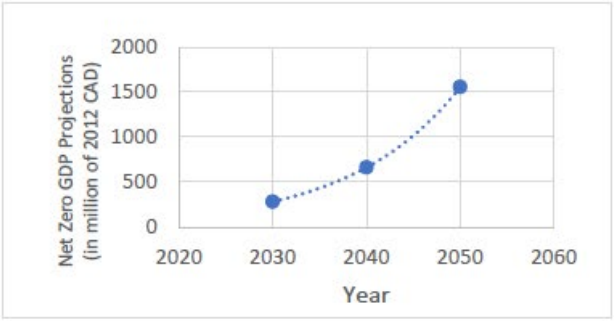
2020 Economic Contribution from Hydrogen in Alberta

211 people	$120 million	$9.7 million	9%
2020 Employment	**2020 GDP**	**2020 Exports**	**Net Zero Pathway CAGR**

Source: Delphi Group Economic Model

Net Zero Pathway Projections[1]





Source: Delphi Group Economic Model

Emerging technology verticals within the hydrogen production and utilization sector include:

- Hydrogen value-chain, including production, use and transportation technologies
- Hydrogen fuel cells and material development

Hydrogen production and utilization companies in Alberta are on the leading edge of the sector. These companies include:

- Air Products Canada Ltd.[i]
- Aurora Hydrogen[ii]
- Enerflex[iii]
- Proton Technologies[iv]
- Quantiam Technologies Inc.[v]
- Western Hydrogen[vi]

Alongside businesses, organizations in Alberta are helping the hydrogen production and utilization ecosystem including:

- Canadian Hydrogen and Fuel Cell Association[vii]
- The Transition Accelerator[viii]
- Canadian Energy Systems Analysis Research[ix]
- University of Alberta[x]
- University of Calgary[xi]
- The Alberta Industrial Heartland Hydrogen Task Force[xii]
- The Southeast Alberta Hydrogen Task Force
- Edmonton Region Hydrogen Hub[xiii]
- Medicine Hat Hydrogen Hub[xiv]

[1] These figures represent the expected employment and GDP growth in the sector if Alberta reaches a net zero economy by 2050.

Some recent investors in Alberta's hydrogen production and utilization ecosystem include:

- ATCO[xv]
- Suncor[xvi]
- Air Products[xvii]
- Emissions Reduction Alberta [xviii]

The hydrogen production and utilisation sector is an emergent market, with a number of start-ups in this field becoming established in the past few years. The sector's job creation has been growing, though current economic status could be improved with increased exports and demonstrated commercial applications of hydrogen. There is a lot of potential for the hydrogen market within Alberta, however a strong narrative and overarching policy are needed to secure hydrogen's place in the energy transition.

Programs and Policy Drivers

Government of Canada's Clean Fuel Standard [xix]requires liquid fuel (such as gasoline, diesel, home heating oil) suppliers to reduce the carbon intensity of liquid fuels by 13% by 2030.

Government of Alberta's Natural Gas Vision and Strategy[xx] aims for large-scale blue hydrogen production with CCUS deployment across the province by 2030. Its goals also include exporting clean hydrogen and hydrogen-derived products to jurisdictions across Canada, North America, and globally by 2040.

The federal government has prioritized hydrogen development through its nationwide Hydrogen Strategy[xxi] which aims to establish Canada as a world leading supplier of hydrogen technologies and achieve net-zero emissions by 2050.

Key Indicators Methodology

Level of Maturity – indicated by the age of cleantech companies operating in the space, as well as the age of policies and regulations. Red – low maturity (policies, companies 1-5 years old); Yellow – moderate maturity (policies, companies 5-10 years old); Green – high maturity (policies, companies 10+ years old).

Current Economic Status – indicated by the subsector market size measured in GDP of 2012 dollars. Red – small market size (GDP of $10 million-$100 million); Yellow – medium market size (GDP of $100-$300 million); Green – large market size (GDP of $300 million or more).

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