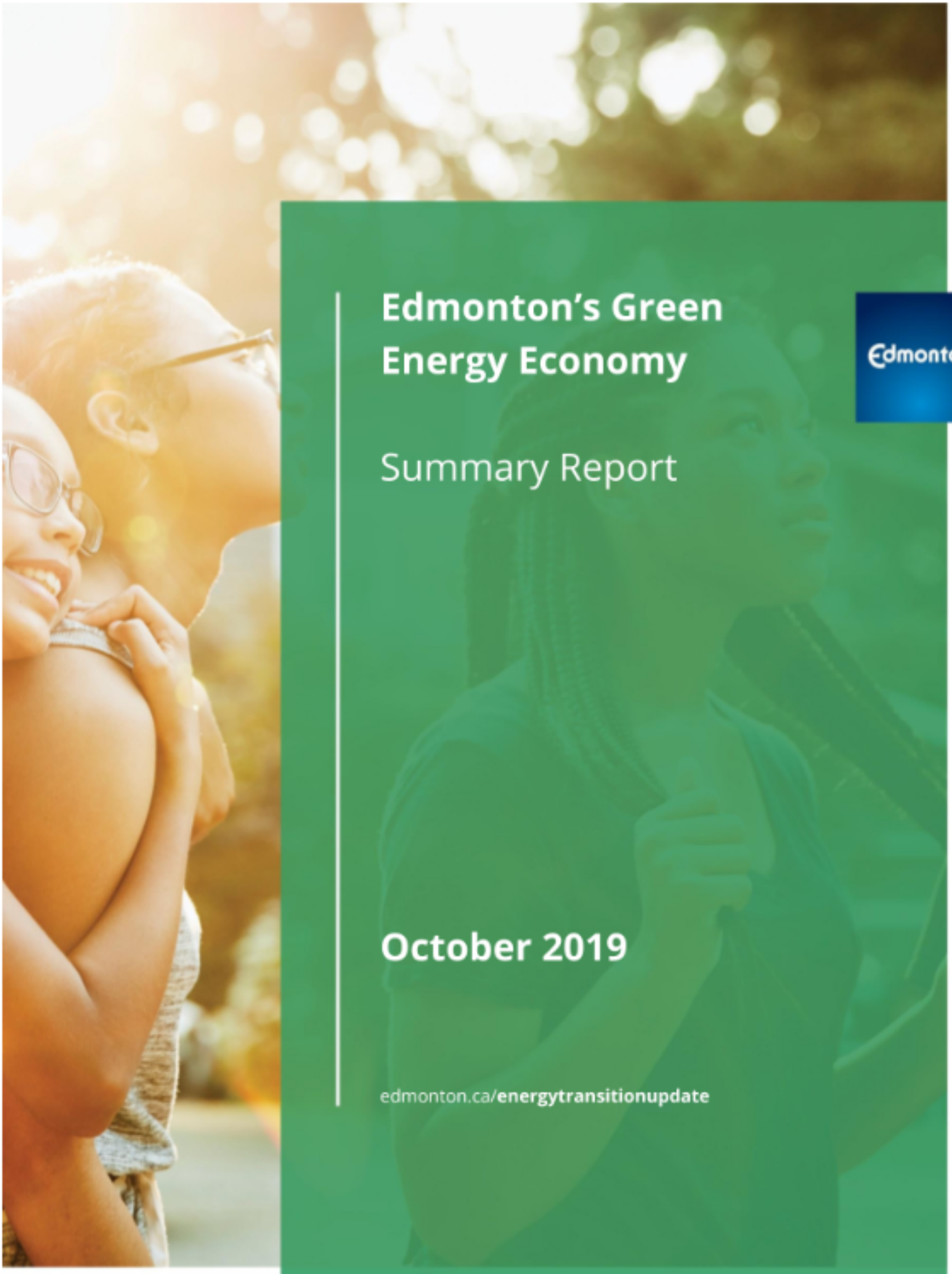


Edmonton's Green Energy Economy

Summary Report

October 2019

edmonton.ca/**energytransitionupdate**

Acknowledgements

The Delphi Group would like to thank the following companies, government agencies, and industry organizations. These key stakeholders and industry leaders provided important resources, insights, and / or data to support this study.

Alberta Clean Technology Industry Alliance

Alberta Energy Efficiency Alliance

Alberta Innovates

Built Green Canada

BYD Canada

Canada Green Building Council

Canadian Automated Vehicle Centre of Excellence

Canadian Geothermal Energy Association

Canadian Wind Energy Association

Centre for Sensors & System Integration

Dialogue Design

EcoAmmo

Edmonton Economic Development

Emissions Reduction Alberta

EnSciTech

Enerkem

EPCOR

Government of Alberta, Economic Development & Trade

Habitat Studio

Landmark Homes

Manasc Isaac Architects

Northern Alberta Institute of Technology

Pacific Western Transport

Passive House Institute

Pembina Institute

Solar Energy Society of Alberta

Stantec

TEC Edmonton

University of Alberta

Urban Development Institute

Photos: Blatchford Development (cover); Muttart Conservatory (above)

Preface

In the Fall of 2015, the Alberta Government introduced its Climate Leadership Plan that plotted a course for Alberta to reduce its greenhouse gas (GHG) emissions and environmental impacts. This Plan and the global shift has created greater opportunities for growth in the green energy economy in Alberta.

The City of Edmonton engaged The Delphi Group in the Fall of 2017 to undertake research and analysis designed to better understand the size and scope of the green energy economy in the Edmonton region and develop recommendations for an action plan designed to support the needs of local businesses, grow key components of the value chain, and attract new investment and talent.

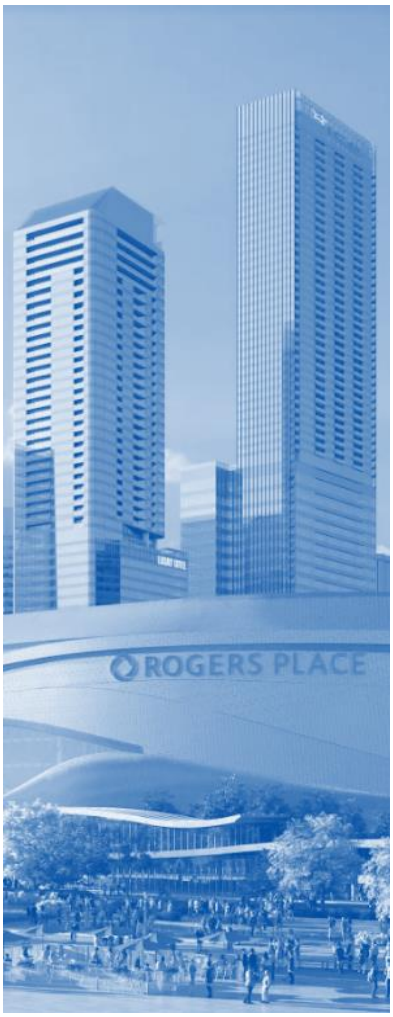
Secondary research for this study included undertaking a broad sweep of more than 50 relevant reports and articles; a review of major industry trends and growth opportunities; a policy analysis on evolving federal, provincial, and regional priorities; and a review of comparative cities and best practice programs.

Sector profiling work included data collection and analysis of statistical sources in order to estimate green energy sector employment and gross domestic product (GDP); compiling lists of relevant companies, projects, investments, and research activities; and performing a value chain assessment of existing strengths, weaknesses, and gaps.

Extensive consultation was also undertaken through 22 interviews with industry leaders and a focus group that brought together key stakeholders from business and government to discuss the local opportunities and challenges for growing Edmonton's green energy economy.

It is hoped that the outcomes from this project will be used to grow Edmonton's green energy sub-sectors and related exports, to support local companies with relevant information, and to encourage the development of strategic partnerships that will help position Edmonton as a growing green energy economy leader.

Photo: Future ICE District (right)



Delphi Group

www.delphi.ca

As a pioneer in sustainability and environmental risk management, The Delphi Group has more than 25 years of experience advancing a greener economy, helping to improve the sustainability of the organizations they work with as well as the local and global communities in which they operate. Delphi's clients benefit from the unique combination of policy expertise, strategic thinking, and technical know-how that Delphi's inter-disciplinary team brings to every project.

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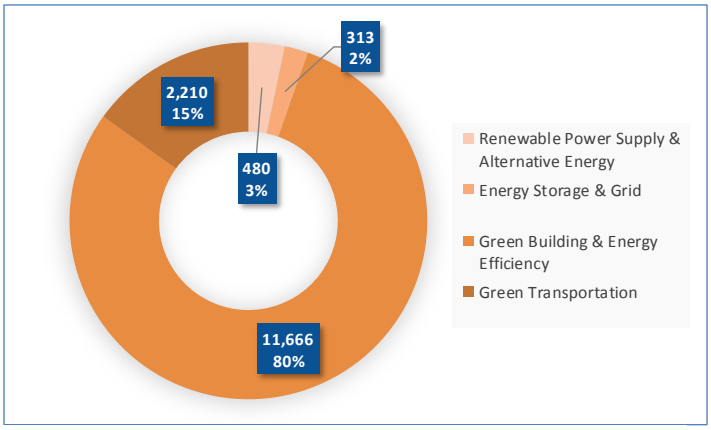
Executive Summary

Technological advancements, increasing demand, and changing policy landscapes towards a green energy economy places increasing pressure on cities to rapidly adapt to change. But with this transition comes opportunity. This report evaluates Edmonton's green energy economy opportunities and strengths across four distinct sub-sectors, providing recommendations on how best to capitalize on the emerging transition to a green energy economy future. These sub-sectors are:

- Renewable power supply and alternative energy;
- Energy storage and grid infrastructure;
- Green buildings and energy efficiency; and
- Green transportation.

Overview

In 2016, Edmonton's green energy economy was responsible for generating $3.59 billion in gross output[1], $1.79 billion in gross domestic product (GDP), and employed approximately 14,669 direct jobs, equal to 2.0% of the region's workforce (as illustrated in Figure ES1).



Source: The Delphi Group

Figure ES1 - Direct jobs in the Edmonton CMA green energy economy in 2016.

Edmonton's green energy economy value chain has strengths that span all elements including: design, engineering and technical services, construction and manufacturing, operations, and broader ecosystem supports.

Anchored by the University of Alberta (UofA) and the Northern Alberta Institute of Technology (NAIT), Edmonton also has a strong tradition of research and development (R&D) with respect to cutting edge technologies. Federal and provincial agencies help fund public and private sector research across the company lifecycle, from startup to well-establish companies. The contributions from these agencies to the green energy sub-sectors, although modest, are critical for Edmonton-based researchers with respect to advancing technologies in this space.

Sub-sector Profiles

The table below provides a number of key take-aways from each of the four sub-sector profiles.

Sub-Sector	Key Take-aways
Renewable Power Supply & Alternative Energy	• Edmonton's Renewable Power Supply and Alternative Energy sub-sector was responsible for approximately 480 direct jobs and $75 million in direct GDP across the value chain in 2016. • Edmonton has existing strengths in project development and engineering, particularly as it relates to solar power production (both rooftop and utility scale projects) and biofuels (including Enerkem's innovative biofuel facility from municipal solid waste). • Alberta's renewable energy procurement process to bring 5,000 MW of renewable electricity on to the grid system by 2030 is helping to drive investment in the province, including a recent award for a 201.6 MW wind farm by Edmonton-based Capital Power.

[1] Gross output measures total economic activity in the production of new goods and services in an accounting period. It is more representative of 'revenue' and is a much broader measure of the economy than GDP, which is limited mainly to final output (finished goods and services).

Energy Storage & Grid Infrastructure	• Edmonton's Energy Storage and Grid Infrastructure sub-sector was responsible for approximately 310 direct jobs and $48 million in direct GDP across the value chain in 2016. • Alberta's announcement to phase out coal generation by 2030 will lead to a large transformation of assets and generation types operating on the smart, inter-connected electricity grid. • Edmonton companies have expertise in smart grid infrastructure development and deployment, especially around planning and integrating related technologies into the transmission and distribution system. • Currently, there are 12 ongoing transmission projects in the Edmonton transmission planning area. • There is an increasing need for equipment, software, and systems to manage the increasing proliferation of intermittent electricity sources, the desire for net metering and energy efficiency, and projections of a larger number of micro-grid installations being constructed over the next decade. • Edmonton has private sector activity on battery systems, as well as ongoing research related to electro-chemistry, energy storage related to lithium ion batteries, and capacitors, at the UofA. • The UoA has also partnered with NAIT to develop a distributed energy management / smart grid demonstration lab which will be commissioned soon.
Green Buildings & Energy Efficiency	• Edmonton's Green Building and Energy Efficiency sub-sector was responsible for approximately 11,670 direct jobs and $1.36 billion in direct GDP across the extensive value chain in 2016, equal to 1.6% of Edmonton's total workforce • Edmonton's northern climate and influx of new residents over the past 15 years has led to strong activity related to green and energy efficient building architecture, design, engineering, and construction. • Edmonton is a leader in Canada with respect to LEED, BOMA BEST, and Built Green certified buildings. • In the commercial space, building owners are shifting to more energy efficient building designs, along with the integration of sensors and building automation systems that can monitor and provide feedback, enabling users and building owners to make smarter decisions around energy use and lower their environmental impacts. • Edmonton is also showing leadership in terms of community-scale projects, such as the downtown ICE District and the Blatchford redevelopment. • In addition, many Edmonton companies are leaders in Alberta in terms of companies focused on building low energy or net zero energy (NZE) homes. • Modular construction / pre-fabrication is another strength of Edmonton-based companies, with solutions design to lower costs and decrease energy demand, while maintaining high quality, precision-built homes. • While large scale manufacturing is not a strength in the Edmonton region, niche manufacturing for green building and energy efficient materials does exist and is a growing segment.
Green Transportation	• Edmonton's Green Transportation sub-sector was responsible for approximately 2,210 direct jobs and $307 million in direct GDP across the value chain in 2016. • The public transport and rail segments are responsible for over 90% of the Edmonton region's Green Transportation jobs, much of which is supported by the movement of large numbers of people and goods via rail and transit. • Edmonton's public transit enjoys one of the busiest light rail transit (LRT) riderships in North America (eighth highest) as of 2014. • The City has taken a number of actions to promote mode shifting, including the approval of a 7.1km network of downtown bike lanes and LRT infrastructure expansions. • Edmonton is also home to extensive research related to green transportation options, including the UofA's Centre for Smart Transportation, the Canadian Automated Vehicles Centre of Excellence, the Advanced Systems for Transportation (a consortium of 34 local and multinational companies focused on developing autonomous systems, including autonomous vehicles), and ACTIVE-AURORA (Canada's first Connected Vehicles test bed).

Value Chain Gaps

Gaps identified for Edmonton's green energy economy include:

- Facilities or sites for piloting / demonstrating new and emerging technologies.
- Commercial manufacturing at a large-scale of technologies and components related to the green economy subsectors: renewable energy, energy storage, buildings, and transportation sectors.
- Investment and financing firms with experience funding green energy sector projects.
- System integrators and project developers with specialized experience in the energy storage sub-sector.
- Global distribution networks for growing the export potential of Edmonton companies focused on the green energy sector.
- Construction trades and builders (primarily residential) experienced in working with energy efficient products / technologies and processes.
- Building operations staff experienced with high-performance buildings and related technology.

Sub-sector Opportunities

Opportunities for Edmonton in the green energy economy are summarized by sub-sector in the table below.

Sub-Sector	Opportunity Areas
Renewable Power Supply & Alternative Energy	• Renewable energy project design & planning • Digitization and automation technologies • Niche manufacturing across the renewable energy value chain • Bioenergy / biofuels / biogas capture & utilization
Energy Storage & Grid Infrastructure	• Energy storage technologies • Micro-grid systems and urban energy storage solutions • Smart grid technologies • Cloud-connected and data analytics services
Green Buildings & Energy Efficiency	• Net zero energy communities • Smart / connected building technologies • Cloud-connected and analytics services • Building design and project delivery software solutions • Energy efficiency retrofits and related professional services • Energy efficient prefabrication and modular construction • Green building materials
Green Transportation	• Vehicle electrification • Autonomous vehicles and artificial intelligence • Goods movement and logistics • Smart transportation technologies

Recommendations & Conclusions

As an energy hub in North America with available talent, Edmonton's green energy economy value chain is already well-developed. Significant strengths lie in Edmonton's expertise related to green building design and construction, as well as solar PV system development, automation / sensors, and smart transportation solutions.

In order to continue growth and diversification of its green energy economy, the City of Edmonton may wish to strategically target efforts around three themes:

1. Ways to support early-stage companies and SMEs;
2. Ways to drive the demand for more localized, community-scale green energy economy projects; and
3. Growing awareness for the opportunities, supporting education, and promoting collaboration across the green energy economy ecosystem.

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1. Introduction

The Shift to a Global Green Energy Economy

A global shift towards a green energy economy is underway, being driven by international climate change concerns, an exploding population which is transitioning from poor to middle-class, and an improved business case for renewable energy and related clean technology. A green energy economy maximizes energy efficiency and produces renewable energy to meet energy demands. The green energy economy utilizes technology that revolutionizes the way that energy is produced, managed, and consumed.

Current technological megatrends that are accelerating the movement toward a green energy economy include an increasing digitalization of energy, buildings, and transportation systems; ubiquitous internet-enabled technology which improves connectivity to make way for internet of things (IoT) solutions; the growth of automation and artificial intelligence (AI); the merging of sustainable technology and infrastructure; efficient community design that is more focused on smart mixed-use developments; and the advancement of electric and autonomous vehicles.

Green energy technologies are becoming more affordable. Large-scale technology development has driven down costs and improved performance for solar photovoltaic (PV) panels, wind turbines, energy storage solutions, and electric vehicles (EVs). Cost reductions have been so dramatic that many renewable energy options are cost competitive with conventional energy sources, reaching grid parity in many parts of the world. This trend was underscored in December of 2017, when three Alberta wind projects were approved to deliver 600 MW of generation at a weighted average bid price of 3.7 cents per kilowatt-hour – a new record in Canada for the lowest renewable electricity pricing.[2] The International Energy Agency projects that wind and solar generation costs are expected to drop another 26% and 57%, respectively, by 2025.[3] These cost reductions help make the ambitious 100% renewable electricity targets from large cities, such as Vancouver, San Diego, and San Francisco possible.[4]

Technological developments are synergistic. Green energy economy megatrends are not isolated. The technologies that make them possible often provide shared efficiencies that can encourage the development of one another. For example, increasing renewable energy generation encourages the adoption of electric vehicles which strengthens the argument for further renewable energy generation. Green energy technologies can work in unison to compound their disruptive potential.

Consumers are more environmentally aware. In addition to cost reductions, consumer preferences have been changing at the grassroots level. Consumers are increasingly concerned about climate change and living less impactful lives. Lifestyle changes are favouring an urban form that consists of high-performance homes and buildings and communities capable of promoting health, well-being, and walkability. Consumers are increasingly attracted to electric vehicles which are currently, or soon to be, offered by most major auto manufacturers. While plug-in cars make up only 0.2% of the global car market in 2017,[5] Bloomberg New Energy Finance predicts that "regulatory support, increased EV commitments from automakers, and the growing role of car sharing, ride hailing and autonomous driving" will drive increased EV adoption until they capture 33% of the global car fleet by 2040.[6]

Public policy influence. Climate change and efforts to achieve a low-carbon economy are at the forefront of many economic, political, and social discussions around the world. Both risks and opportunities are rapidly evolving across many industries, with the long-term trajectory towards greater concern and an increase in both the frequency and intensity of government efforts to lower emissions. International concern has been demonstrated by the near unanimous ratification of the United Nation's Conference of the Parties (COP 21) Agreement (i.e., the "Paris Agreement"), which aims to limit global warming to "well below 2°C above pre-industrial levels".

[2] See: https://www.aeso.ca/market/renewable-electricity-program/rep-round-1-results/
[3] Refers to onshore wind. See: http://cleanenergycanada.org/wp-content/uploads/2017/03/CEC_TER-Report-Spring-2017_web.pdf
[4] See: https://www.sierraclub.org/sites/www.sierraclub.org/files/blog/RF100-Case-Studies-Cities-Report.pdf
[5] See: https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf
[6] See: file:///C:/Users/bedwards/Downloads/Electrifying%20insights%20-%20How%20automakers%20can%20drive%20electrified%20vehicle%20sales%20and%20profitability_vF.pdf

Federal policy. In order to determine whether the Paris Agreement will be met, participating nations are requested to submit Nationally Determined Contributions (NDCs) that outline long-term climate actions post 2020. Canada's NDC sets a 30% economy-wide GHG emissions reduction target below 2005 levels by 2030.[7] Canada's long-term goal is to reduce emissions by 80% from 2005 levels by 2050.[8] While much effort has been put into individual actions and projects to reduce GHG emissions, a low carbon economy will ultimately be required to achieve the significant GHG emission reductions required to reach these goals.

In 2016, the federal and provincial governments adopted the Pan-Canadian Framework on Clean Growth and Climate Change (i.e., the "Framework"),[9] which includes commitments to carbon pricing complemented by policies and programs for reducing greenhouse gas (GHG) emissions. These policies will increase the cost of fossil fuels and make renewables more competitive. The Framework will develop a series of policies and regulations to promote collaboration of electricity grid interconnections, building codes, and a zero-emissions vehicle strategy. Other outcomes of the Framework will include new programs for green infrastructure investments and deepening clean technology innovation and implementation.[10]

Provincial policy. At the provincial level, the Government of Alberta (GoA) introduced its Climate Leadership Plan (CLP) in 2015 with the following key aspects:

- Implementing economy-wide carbon pricing;
- Phasing out pollution from coal-generated electricity by 2030;
- Tripling renewable energy to supply 30% of generation by 2030;
- Creating Energy Efficiency Alberta to deliver cost saving programs; and
- Reducing emissions from the oil and gas sector.

The GoA has shown a commitment to the CLP in its 2017 fiscal plan. $5.4 billion dollars over the next three years is designated for climate leadership funding with $1.274 billion of that allocated to green infrastructure, $998 million towards renewable energy projects, transformative innovation and technology development, and bioenergy initiatives, and $566 million allocated to support energy efficiency and small scale renewable energy projects.[11]

The GoA plans to support an additional 5,000 MW of renewable capacity through 200-400 MW calls for power every few years as it phases out coal-generated electricity. The first round awarded 600 MW of wind capacity in December of 2017 due to record low generation prices. These bids will help Alberta achieve its CLP of 30% renewable capacity target by 2030.

Municipal policy. Since 2008, Edmonton has required all new buildings and major renovations to be constructed to meet high-performance building requirements, which were recently bolstered by the 2017 Sustainable Building Policy, setting new and ambitious standards for building energy efficiency. In 2011, The Way We Green strategic plan set a 30-year environmental strategy to help Edmonton achieve a sustainable and resilient future, with a goal for Edmonton to become a carbon-neutral city. Edmonton's more recent 2015 Energy Transition Strategy includes actions to reduce GHG emissions and help achieve the Paris Agreement, increase energy efficiency, and participate in "possibly one of the greatest economic opportunities in history."[12] Edmonton's 2012 GHG Emissions Reduction Plan aims to achieve a 50% reduction from city operations by 2020 (from 2008 levels) and an 80% reduction by 2050.[13]

[7] See: http://www4.unfccc.int/ndcregistry/PublishedDocuments/Canada%20First/Canada%20First%20NDC-Revised%20submission%202017-05-11.pdf

[8] See: https://www.newswire.ca/news-releases/government-of-canada-sets-ambitious-ghg-reduction-targets-for-federal-operations-665237843.html

[9] Saskatchewan and Manitoba have not yet adopted the Pan-Canadian Framework https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html

[10] See: https://www.canada.ca/content/dam/themes/environment/weather/climatechange/PCF-FirstSynthesis_ENG.pdf

[11] See: http://finance.alberta.ca/publications/budget/budget2017/fiscal-plan-complete.pdf

[12] See: https://www.edmonton.ca/city_government/documents/EnergyTransitionStrategy.pdf

[13] See: https://www.edmonton.ca/city_government/documents/PDF/CityOperationsGHGManagementPlan.pdf

Profiling Edmonton's Green Energy Economy Opportunities

Technological advancements, increasing demand, and changing policy landscapes towards a green energy economy places increasing pressure on cities to rapidly adapt to change. But with this transition comes opportunity. For example, market revenue from autonomous vehicles, representing a small segment of the green energy economy, is expected to become a $126.8 billion industry by 2027.

Cities are economic powerhouses that bring together green energy investment, innovation, and entrepreneurship. They may be best suited to seize these opportunities and, in exchange, be rewarded with a vibrant, diversified economy.

Leadership in Edmonton is openly committed to developing Edmonton's green energy economy. Mayor Don Iveson has expressed a keen interest in accelerating Edmonton's leadership on energy transition and climate change and encourages the city to lead by example.

> *"Working with partners, we can transition to green/clean energy sooner rather than later. Our kids and grandkids demand and deserve nothing less."*
>
> *Source: Mayor Don Iveson*

This report evaluates Edmonton's green energy economy, which has been divided into four distinct sub-sectors. These sub-sectors, and the segments that comprise them, are illustrated in Figure 1.

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Author's Note on Definition: The scope as defined for this study focused on renewable energy and related technologies. While Delphi Group recognizes there are non-renewable energy related technologies that could be considered part of the green energy economy given their positive impact on reducing energy demand and/or GHG emissions (e.g., carbon capture and utilization, co-generation, etc.). these technologies were not included in this study.

Source: The Delphi Group

Figure 1 - Edmonton's four green energy economy sub-sectors and related segments profiled in this report.

The sections that follow showcase some of Edmonton's key players, projects, and activities; identify Edmonton's potential opportunities for growth and further investment based on existing value chain strengths and gaps; and provide strategic considerations that will help Edmonton maximize its opportunities and minimize its risks. The report is broken out into the following chapters:

- **Chapter 2:** Provides an overview of Edmonton's green energy economy at a macro-level.
- **Chapter 3:** Provides more detailed profiles of Edmonton's four green energy economy sub-sectors.
- **Chapter 4:** Identifies gaps in Edmonton's green energy economy value chain.
- **Chapter 5:** Highlights potential opportunity areas within Edmonton's green energy economy sub-sectors.
- **Chapter 6:** Provides recommendations for accelerating the growth of Edmonton's green energy economy.
- **Chapter 7:** Provides the key conclusions from the research.

In addition, Appendices include a detailed project methodology (Appendix A) and SWOT analysis (Appendix B).

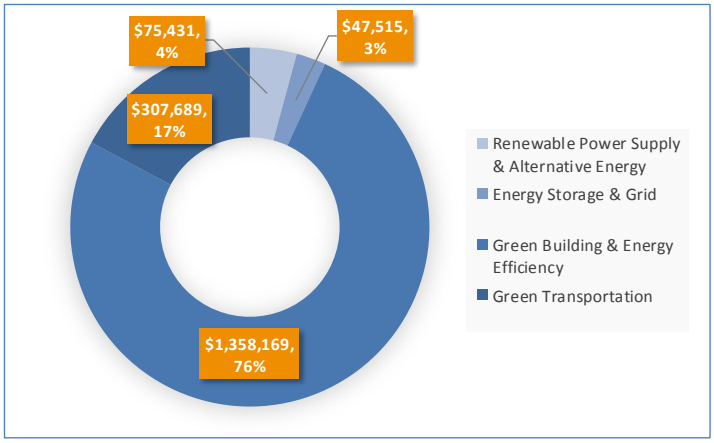
2. Edmonton's Green Energy Economy Macro-Level Profile

Edmonton's green energy economy generates a diverse set of activity. This study exclusively focused on the following sub-sectors:

- Renewable power generation & alternative energy;
- Energy storage & grid infrastructure;
- Green building & energy efficiency; and
- Green transportation.

Edmonton's green energy economy was responsible for generating **$3.59 billion** in gross output[14], **$1.79 billion** in gross domestic product (GDP), and employed approximately **14,669 jobs**, equal to 2.0% of the Edmonton Census Metropolitan Area's (CMA) workforce in 2016.[15] [16]

Leveraging the growing public interest to reduce environmental impacts, lower energy bills and improve transportation, the four sub-sectors profiled in this report present an excellent foundation upon which Edmonton can continue to grow economic activity related to green energy.



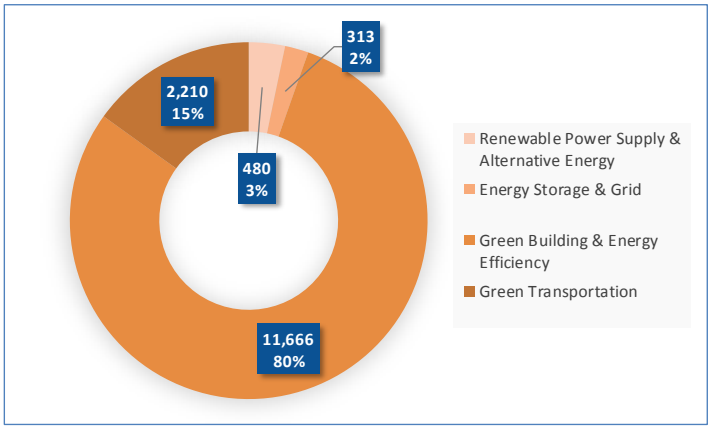
Source: The Delphi Group

Figure 2 - Direct GDP generated from the Edmonton CMA green energy economy in 2016.

Value Chain Strengths

Edmonton's green energy economy value chain has strengths that span all elements including: design, engineering and technical services, construction and manufacturing, operations, and broader ecosystem supports, although not all elements are present in each sub-sector.

By leveraging Edmonton's existing workforce that is experienced with all aspects of the energy industry, the green energy economy value chain can continue to diversify and strengthen in the coming years. Many transferable skills and knowledge in the existing workforce can be applied to the green energy economy. Careers in management, professional services, engineering, science, project management, ICT, construction, trades, and manufacturing all have elements that can be applied to strengthen the four sub-sectors in Edmonton.



Source: The Delphi Group

Figure 3 - Direct jobs in the Edmonton CMA green energy economy in 2016.

For the renewable and alternative energy system subsector, Edmonton has existing strength in project development and engineering expertise. In particular, expertise relates to solar power production and biofuels. Edmonton companies have also been leaders in smart grid infrastructure development and deployment, especially around planning and integrating smart technologies into the transmission and distribution system.

[14] Gross output measures total economic activity in the production of new goods and services in an accounting period. It is more representative of 'revenues' and is a much broader measure of the economy than GDP, which is limited mainly to final output (finished goods and services).

[15] Note: Estimates are based on a geographic scope equivalent to Edmonton's Census Metropolitan Area. Total employment for Edmonton's Census Metropolitan area in December 2016 was 747,300 jobs according to Statistics Canada.

[16] Comparatively, using the same definition for the green energy economy, the Calgary CMA has 16,109 direct jobs (representing 2.0% of Calgary's total work force based on Calgary's employment estimate of 815,700 in December 2016) and $3.74 billion in direct GDP. See: https://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/lfss04k-eng.htm

For the green building and energy efficiency sub-sector, Edmonton's northern climate and influx of new residents over the past 15 years has led to strong activity related to efficient building design, architecture, engineering, and construction. Edmonton's cold winters and hot summers demand innovative thinking around energy use. In addition, many Edmonton companies are leaders in Alberta in terms of companies focused on building low energy or net zero homes.

While large scale manufacturing is not a strength in the Edmonton region, niche manufacturing for green building and energy efficient materials is present. Entrepreneurs are innovating new products that will both reduce energy use and environmental impacts.

Edmonton homebuilders are experts in pre-fabrication and modular construction. The number of homes built using this approach continues to grow, and offers solutions to lowering costs and decreasing energy consumption, while maintaining high quality, precision-built homes. In the commercial space, building owners are shifting to more energy efficient building designs, along with integration of sensors that can monitor and provide feedback, enabling users and building owners to make smarter decisions around energy use and lower their environmental impacts.

Research, Innovation & Investment

Anchored by the University of Alberta and the Northern Alberta Institute of Technology, Edmonton has a strong tradition of research and development with respect to cutting edge technologies, although the funding in the green energy subsectors remains modest.

Federal and provincial support for research and development exists through Natural Resources Canada (NRCan), the National Research Council of Canada (NRC), Sustainable Development Technology Canada (SDTC), the National Sciences and Engineering Research Council of Canada (NSERC), and Alberta Innovates. These agencies help fund either public or private sector research across the company lifecycle, from startup to well-establish companies. The contributions from these agencies are critical for Edmonton-based researchers to advance technologies related to the green economy.

Federal funding to Alberta's academic researchers is primarily through NSERC, although private research funding is not uncommon. From 2012-2017, 7.7% of all NSERC grants in Alberta have gone to green energy economy sub-sectors, equal to approximately $40.7 million. Of the NSERC grant funding in Alberta allocated to green energy economy sub-sectors since 2012, approximately 42% or $16.9 million has targeted post-secondary institutions in Northern Alberta (i.e., Edmonton region).

Specialized pockets of research expertise have developed at Edmonton's post-secondary institutions in areas around machine intelligence, autonomous vehicles, intelligent transportation systems, and green building technologies (see Table 1). Building on this research, there remains a need to build capacity in Edmonton for industrial demonstrations and financing technologies from the lab scale to commercial scale. Capitalizing on the under-employed and available talent from the oil and gas sector could help companies further advance their R&D efforts in the green energy economy sub-sectors.

In addition, the Edmonton Research Park (ERP) is home to more than 1,500 members at 55+ companies working in diverse fields, from biotechnology to energy. Start-ups and growing companies can access a variety of workspaces; on-site programs, access to soft-landing programs; personalized referrals to support and funding agencies; and facilitated access and collaboration with local, national and international communities of accelerators, science parks, and incubators.

Edmonton Research Park offers a range of services to research-driven companies including operating two buildings in the park designed to nurture research initiatives: The Advanced Technology Centre, and the Biotechnology Business Development Centre. Land is available for qualified companies planning to build research facilities within four areas of focus: biotechnology, nanotechnology, clean energy and oil and gas support.

Table 1 - Green Energy Economy Related Research & Innovation Initiatives Underway at Edmonton Post-Secondary Institutions.

Initiative	*Sub-sector(s)*	*Description*
Alberta Machine Intelligence Institute ➔ ***University of Alberta***	Applications across all sub-sectors	AMII is the Alberta Machine Intelligence Institute, a research lab at the University of Alberta previously known as the Alberta Innovates Centre for Machine Learning (AICML). We work to enhance understanding and innovation in a number of subfields of machine intelligence. Research areas include data mining and analysis, human-machine interaction, information extraction and visualization, machine learning)
Energy Systems Research Group - Department of Electrical and Computer Engineering ➔ ***University of Alberta***	Energy Storage and Grid / Renewable Power	Current research includes: distributed generation and microgrids; smart grids; renewable energy including PV, wind and biogas systems; electric energy storage; electric and hybrid electric vehicles ; power electronics topologies, control and PWM techniques; industrial variable speed drive systems; power electronics for high speed machines; power electronics for renewable energy interfaces; electrical machines; computational electromagnetism; power quality; power system signaling, monitoring and measurements; real-time simulation of large-scale power electric and power electronic systems; electromagnetic transient analysis; parallel and distributed computing technologies; industrial, commercial and utility system reliability; power system stability; and power system operation and controls.
Centre for Smart Transportation ➔ ***University of Alberta***	Green Transportation	The Centre for Smart Transportation is housed in the Department of Civil and Environmental Engineering with a vision to improve multi-modal transportation mobility, safety and sustainability in cold climate regions.
Centre for Applied Technology ➔ ***Northern Alberta Institute of Technology (NAIT)***	Green building / Energy efficiency	Open in August 2016, the Centre for Applied Technology (CAT) is the largest building on NAIT's Main Campus. It hosts programs in Sustainable Building and Environmental Management, and Applied Sciences and Technology.
Centre for Sensors and System Integration ➔ ***NAIT***	Green buildings/ smart grid/ green transportation	NAIT's Centre for Sensors and System Integration is a research centre funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). Created to partner with small and medium enterprises seeking coordinated innovation development services, the centre is staffed with highly qualified specialists and technologists experienced in providing prototype development solutions. The centre helps industry partners develop prototype devices that address sensor-based challenges in resource extraction, agriculture, biomedical, and advanced technology enterprises.
Office of Research and Innovation - Construction and Trades ➔ ***NAIT***	Green Building and Energy Efficiency	Areas of focus in the School of Skilled Trades include: Building Environmental Systems & Technologies; Industrial Safety Robotic Welding; and Smart Construction and Materials.

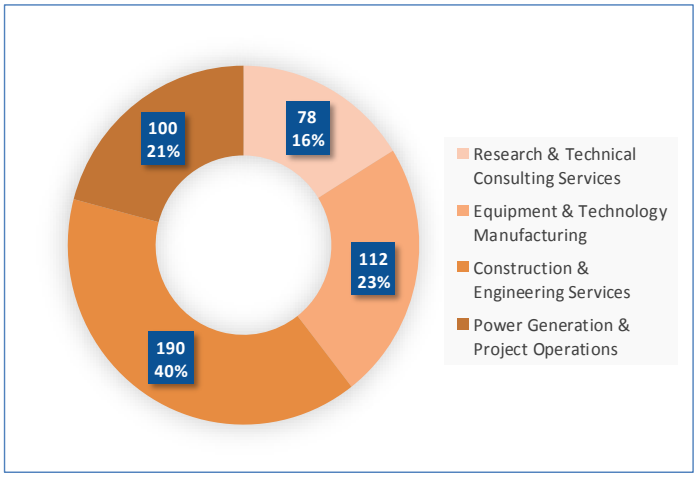
3. Green Energy Sub-Sector Profiles

Renewable Power Supply & Alternative Energy

Jobs & GDP

In 2016, Edmonton's Renewable Power Supply and Alternative Energy sub-sector provided approximately **480 direct jobs** and **$75 million** in direct GDP across the value chain.[17, 18] As illustrated in Figure 4, employment was highest in the construction and engineering services segment, equal to 190 jobs or approximately one-third (40%) of employment. The next largest segments included equipment and technology manufacturing (112 jobs); power generation and project operations (100 jobs); and research and technical consulting services (78 jobs).

In terms of direct GDP from the sub-sector in 2015, 69% of the total comes from the power generation and project operations (32%) and construction and engineering services (37%) segments. Combined, these two sectors equal approximately $52.5 million (see Figure 5).



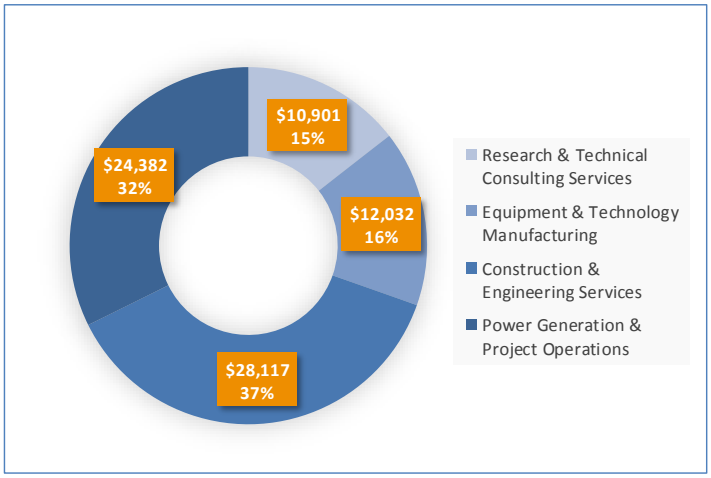
Source: The Delphi Group

Figure 4 - Direct jobs in Edmonton's Renewable Power & Alternative Energy sub-sector in 2016.

Projects & Activities

Alberta has been a leader in Canada, integrating renewable energy projects onto the interconnected electricity system from as far back as 1993. By the end of 2016, Alberta had more than 2,800 megawatts (MW) of installed renewable power capacity (including hydro, wind, biomass, and solar), making up approximately 17% of total installed capacity.

In September 2016, there were 61 utility-scale renewable energy generation projects proposed by industry, with a total power capacity of approximately 7,460 MW. But a combination of depressed electricity prices over the past two years, an existing oversupply of capacity, and the transition from an energy-only market to a capacity market with uncertainty as to how the new market will function, has slowed down project development on the interconnected electricity system and the growth of new, utility-scale renewable energy projects has been limited. Renewable energy developers, participants and observers are eagerly awaiting the new capacity market rules to see which projects will be favourable going forward.



Source: The Delphi Group

Figure 5 - Direct GDP from Edmonton's Renewable Power & Alternative Energy sub-sector in 2016. ($ thousands).

[17] Note: Estimates are based on a geographic scope equivalent to Edmonton's Census Metropolitan Area.

[18] Comparatively, for this subsector, the Calgary CMA had 655 direct jobs an $102 million in direct GDP in 2016.

Table 2 - Total installed capacity in Alberta by year and technology type (MW / % of total capacity).[19]

Year	2013		2014		2015		2016	
Coal	6,258	42.9%	6,258	40.9%	6,267	38.8%	6,273	38.0%
Natural Gas	5,811	39.8%	6,161	40.2%	6,953	43.1%	7,323	44.3%
Hydro	900	6.2%	900	5.9%	902	5.6%	916	5.5%
Wind	1,113	7.6%	1,459	9.5%	1,491	9.2%	1,491	9.0%
Biogas & Biomass	417	2.9%	438	2.9%	424	2.6%	424	2.6%
*Others	98	0.7%	98	0.6%	97	0.6%	97	0.6%
Total	**14,597**		**15,314**		**16,133**		**16,524**	

** Others include oil, diesel, and waste heat*

Source: Alberta Utilities Commission

In total, the installed capacity of renewables in 2016 was up 401 MW over 2013. As illustrated in Table 2, wind energy capacity has been the largest growth area since 2013 increasing an additional 378 MW by 2016. Hydropower and biogas / biomass installed capacity has stayed more or less constant over the past four years.

In terms of generation, hydropower and biogas / biomass were down in terms of gigawatt hours (GWh) of production between 2013 and 2016. Wind generation increased by 1,301 GWh in 2016 from the 3,107 GWh in 2013, equal to 5.2% of total electricity generation in the province.

Despite the current slowdown in developing interconnected renewable energy projects, Alberta's renewable energy procurement process to bring 5,000 MW of renewable electricity on to the grid system by 2030 is helping to drive investment in the province. Results from Round 1 of Alberta's Renewable Electricity Program (REP) were announced in December 2017. Approximately 600 MW of wind energy will be built through four projects and by three proponents, including Edmonton based Capital Power Corporation, which will build a 201.6 MW facility near Medicine Hat.[20] A new, record low price for wind electricity in Canada was set during the auction, with the average weighted price of $37/MWh (3.7 cents/kWh). Future REP rounds are expected in the coming years.

Bioenergy

Alberta has abundant biomass resources primarily in the northern part of the province. Conversion of biomass into higher value products, such as bioenergy, is an opportunity to expand the economic impact from this natural resource beyond traditional commodities.

According to Alberta Energy, the province has 20 million tonnes of annual waste in potential biomass feedstocks which can be converted to bioenergy.[21] Alberta has approximately 30 biomass or biofuel plants in Alberta (see Figure 6), that contribute an estimated $300 million in labour income and $788 million to provincial GDP.[22]

From the map in Figure 6, a significant number of facilities exist in northern Alberta, aligning with the existing resource capacity.

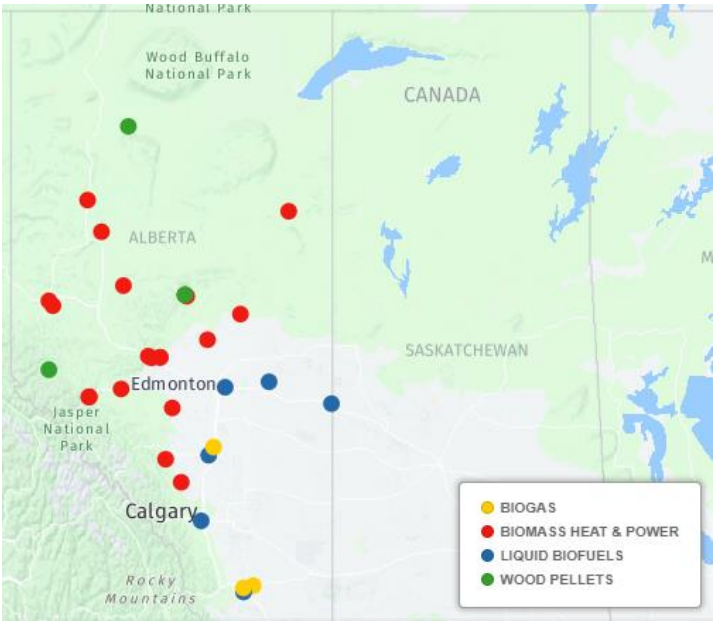
[19] See: http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx
[20] See: http://www.capitalpower.com/generationportfolio/CA/Pages/Whitla-Wind.aspx
[21] See: http://www.energy.alberta.ca/BioEnergy/bioenergy.asp
[22] See: http://www.virescosolutions.com/wp-content/uploads/2015/10/Bioenergy-Producer-Report-Card-FINAL_20150901.pdf

Within the Edmonton region, Capital Power has a 5 MW biogas facility at Clover Bar Landfill, and Enerkem Alberta Biofuels has the world's first waste-to-biofuels facility that converts solid municipal waste into biofuels and biochemicals.[23] Outside of Edmonton, within a 160-kilometer radius there are eight bioenergy facilities (see Table 3).

Alberta's Bioenergy Producer Credit Program originally expired in 2016, but has been renewed for 2.5 years up until March 2020. The renewed program has a more limited scope, focusing exclusively on supporting liquid biofuel production and stand-alone bio-power production.

As Alberta diversifies from fossil fuel-based power sources, biofuels have the opportunity to help fill the gap, reducing the need for additional natural gas. Edmonton's location and proximity to biomass resources makes the city well-positioned for contributing to the growth of the bioenergy industry.

In addition to the Bioenergy Producer Credit Program, ERA has funded approximately 34million dollars worth of bioenergy projects in Edmonton and northern Alberta.



Source: Alberta Bioenergy Producer Report Card (2015). Advanced Biofuels Canada.

Figure 6 - Map of Alberta bioenergy production plants by location

Table 3 - Bioenergy production plants within 160 km of Edmonton

Company	Location	Facility Type	Energy Type/ Capacity	Other Bioproducts
Alberta Pacific Forest Industries	Grassland	Wood waste cogeneration	Electricity (42 MW) / Heat	Methanol
Verdan Energy	Jarvie	Biogas (updraft gasification)	Electricity (16.5 MW)	Wood ash
West Fraser Mills	Blue Ridge	Residual biomass	Heat (966,000 GJ)	
West Fraser Mills	Blue Ridge	Wood biomass	Heat (966,000 GJ)	
Millar Western Forest	Whitecourt	Biogas (anaerobic digestion)	Electricity (4.2 MW) / Heat (7.42 GJ/hr)	
Whitecourt Power LP	Whitecourt	Bioenergy (forest residuals)	Electricity (25 MW) / Heat (30 GJ/hr)	Wood ash (6000 t/yr)
Verdant Energy Ltd	Drayton Valley	Fluidized bed boiler (wood residuals)	Electricity (10.5 MW)	Wood ash
Enerkem	Edmonton	Solid waste gasification		Ethanol (38 million L/yr)
Future Fuel	Two Hills	High starch grain (wheat) conversion		Ethanol (40 million L/yr); wet distillers grains and fertilizer
Lethbridge Biogas	Lacombe	Thermal hydrolysis (waste organic material)	Electricity (1.4 MW) / Heat	Fatty acids, organic fertilizer
Permolex Ltd.	Red Deer	Integrated grain fractionation		Ethanol (45 million L/yr); wet distillers grains

Source: Advanced Biofuels Canada[22]

[23] See: http://enerkem.com/facilities/enerkem-alberta-biofuels/

Specific industrial bioenergy / biofuel facilities near Edmonton include:

- Biogas co-generation (electricity and thermal energy) via anaerobic digestion (Millar Western – Whitecourt, AB)
- Electricity production from woody biomass (Verdant Energy – Jarvie, AB); and
- Ethanol production from grains and municipal solid waste (Enerkem's Alberta biofuels facility – Edmonton, AB).

The **Enerkem Alberta Biofuels facility** plant is a full-scale biofuel production facility taking municipal solid waste from Edmonton and producing ethanol and methanol. This facility is the first to ever sell its ethanol under the United States Renewable Fuel Standard. Over 100,000 metric tonnes of solid waste are diverted from Edmonton landfills every year.

For more information, see: http://www.enerkem.com/

Hydroelectricity

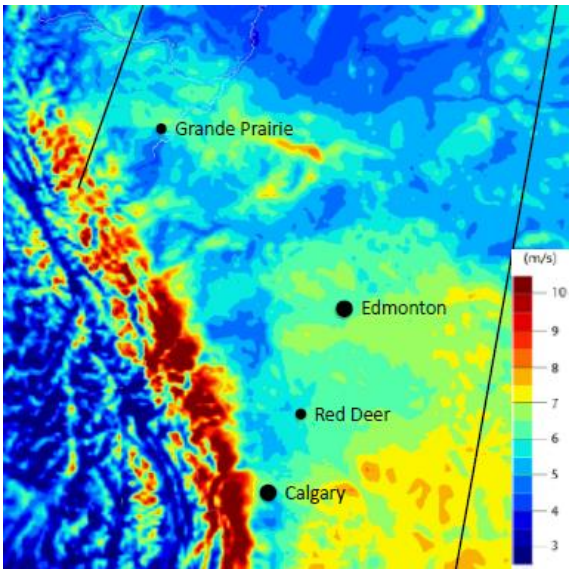
Historically, hydro provided a much larger contribution to Alberta's electricity supply. Over time it has decreased and currently offers about 6% of total installed capacity. The Canadian Hydro Association estimates that Alberta still has more than 11,500 MW of remaining economically viable hydro potential, including both reservoir and run-of-the-river projects. [24] However, with the majority of hydro potential in the north, far from population centres in the south, and a shift towards more decentralized energy and natural gas, the opportunity for hydro does not appear to be significant.

Wind

Alberta is currently Canada's third largest producer of wind energy (following Ontario and Quebec), with the third highest amount of installed capacity for wind energy as of December 31, 2016.[25] A total of 38 projects exist in Alberta with a combined installed capacity of 1,479 MW. Approximately 5.5% of Alberta's electricity demand was supplied by wind in 2016.[26]

The average wind energy resource map for Alberta shown in Figure 7 highlights the strong resource base in southern Alberta, with weaker wind resource potential in northern Alberta. Consequently, Edmonton has limited activity related to the Alberta's wind industry as many companies are located in Calgary and further south.

Overall, the opportunity for wind energy economic growth in the Edmonton region will be limited somewhat by proximity to the wind resource, although Edmonton-based companies are able to participate as suppliers across the value chain.[27]



Source: Canadian Wind Energy Atlas, Government of Canada

Figure 7 - Wind energy resources in Alberta.

[24] See: http://history.alberta.ca/energyheritage/energy/hydro-power/hydroelectricity-in-alberta-today.aspx
[25] See: https://canwea.ca/wind-energy/installed-capacity/
[26] See: https://www.aeso.ca/download/listedfiles/2016-Annual-Market-Stats.pdf
[27] See: https://www.aeso.ca/market/renewable-electricity-program/rep-round-1-results/

Solar Photovoltaic (PV)

Unlike wind, Alberta's solar resource potential is less disparate between northern and southern Alberta. As of November 2017, there were approximately 2,067 solar PV systems installed in Alberta, with a total installed capacity of more than 20 MW.[28] Based on job and investment estimates by the Canadian Solar Industries Association (CanSIA), the 20 MW represents approximately $41.3 million in investment and 250 direct full-time equivalent (FTE) construction jobs.[29] The Solar Energy Society of Alberta lists 98 solar providers in Alberta, 52 of which are based in and around Edmonton.[30] Edmonton's solar education program has been identified as an important tool in helping to grow solar knowledge in the Edmonton region which, in turn, has reduced the burden on local businesses to educate the public, enabling them to spend more of their time on growing their businesses.

Supporting solar business growth is Alberta's micro-generation regulation which enables small-scale generation to be interconnected into Alberta's electricity system. Systems up to 5 MW are now eligible for consideration as micro-generators. As part of the regulation, transmission providers must accept hookups for micro-generation systems. Those participating are paid for their generation based on market pool or wholesale prices depending on the size of the micro-generation project.

The levelized cost of solar electricity in Alberta has not yet reached that of other regions without financial incentives in place, although costs have been rapidly decreasing.

To help address the financing barrier, the Alberta government through Energy Efficiency Alberta is offering a residential and commercial solar program that provides rebates to homeowners, businesses, and non-profits that install solar PV systems, up to $10,000 for a 0 to 15 kW system, and $500,000 for a 0 to 5 MW system.[31]

In addition, Emissions Reduction Alberta (ERA) has supported solar projects throughout Alberta providing over $41.6 million in financing.

Edmonton's largest solar photovoltaic array is a 153.8 kW system that can be found on the Eastgate office building (see sidebar). Recently, EPCOR has proposed a 12 MW facility near the Cameron Heights neighbourhood, which would be the largest solar farm in Alberta.

Solar developers in and around Edmonton include ATCO and SkyFire Energy, along with many SMEs that provide services along the EPC spectrum for small to larger sized installations. Solar energy is one of Edmonton's renewable energy strengths, and will present an opportunity for growth in the future as technology continues to improve and awareness and understanding of solar continues to increase amongst the local supply chain.

Environment Canada's Eastgate office building in Edmonton is covered by a 153.75 kW solar panel array that was installed in 2013.

For more information, see:
https://greatcanadiansolar.com/projects/project/eastgate-office-building

https://solaralberta.ca/case-studies/eastgate-office-building

[28] See: https://solaralberta.ca/
[29] See: http://solaralberta.ca/sites/default/files/canwea_-_cansia_final_submission_sept_30.pdf
[30] See: https://solaralberta.ca/directory/alberta-solar-providers
[31] See: https://www.efficiencyalberta.ca/solar/

Geothermal Energy (Power & Heating)

There exists a large technical potential to use geothermal energy for electricity in Alberta, although there are no commercial geothermal power plants in the province at present. However, there is growing interest within the Provincial Government for geothermal as it could lead to the active redeployment of currently idle drilling rigs and create employment for Albertans.[32] Unfortunately, there is no legal framework for obtaining the drilling permits required for geothermal wells and ministerial approval is required for any geothermal installation. This lack of framework is preventing activity from proceeding at present.

Despite the lack of framework, proponents are trying to break through the current barriers and demonstrate the geothermal opportunity to Albertans. Research is currently underway at the University of Alberta to map the potential for geothermal power across western Alberta in a partnership with Alberta Innovates Energy and Environment Solutions.[33] The work includes mapping water reservoirs several kilometres underground that could be hot enough to convert into electricity using a turbine mechanism. Existing research, suggests that the technical potential for geothermal in Alberta is fairly significant.[34] At 14% recovery, the generation potential is upwards of 60,000 MW at a depth of 3.5 kilometres.

In Hinton, West of Edmonton, the town is teaming up with University of Alberta researchers and Epoch Energy on a proposal to use geothermal energy from the bottom of a nearby abandoned gas well to heat its downtown core.[35] Near Leduc, there is a proposed geothermal project that will tap into the heat found near the Leduc #1 well – the well that in 1947 accelerated the conventional oil boom in Alberta.

In addition to geothermal power, geothermal energy is used to heat or cool homes by drilling to much shallower depths and using heat pumps to circulate warm or cool air or liquid depending on the season. A number of companies and specialty contractors are focused on the installation of this "geo-exchange" technology in the Edmonton region, including NuEnergy, Envirotech Geothermal, and Revolve Engineering. Others are actively manufacturing heat exchangers and related hydronics equipment.[36]

[32] See: http://www.devondispatch.ca/2017/10/16/geothermal-well-repurposing-project-moving-ahead

[33] See: http://www.cbc.ca/news/canada/calgary/geothermal-research-alberta-1.3616014

[34] The technical potential is essentially the fraction of the theoretical potential that can be used under the existing structural and ecological restrictions, as well as legal and regulatory allowances.

[35] See: http://www.cbc.ca/news/canada/edmonton/hinton-geothermal-energy-abandoned-wells-alberta-1.4308997

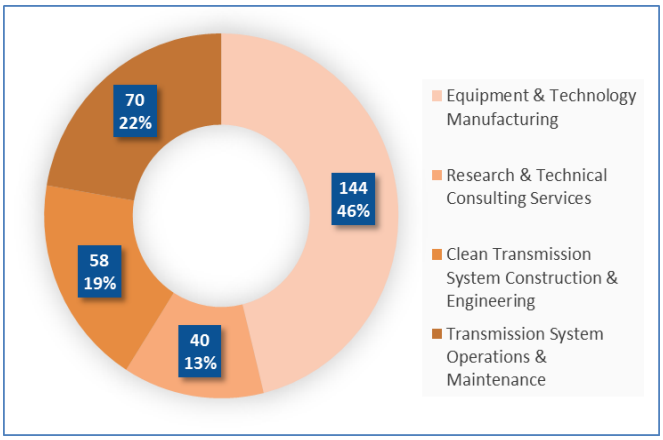
[36] See NRCan backgrounder on heat pumps:
http://www.nrcan.gc.ca/energy/publications/efficiency/residential/heating-heat-pump/6823

Energy Storage & Grid Infrastructure

Jobs & GDP

In 2016, Edmonton's Energy Storage and Grid Infrastructure sub-sector was responsible for approximately **310 direct jobs** and **$48 million** in direct GDP across the value chain.[37] As illustrated in Figure 8, employment was highest in equipment and technology manufacturing, equal to 144 jobs or nearly half (46%) of all employment. The next largest segments included transmission system operations and maintenance (70 jobs); clean transmission system construction and engineering (58 jobs); and research and technical consulting services (40 jobs).

In terms of direct GDP from the sub-sector in 2016, 36% is related to equipment and technology manufacturing, while 31% was generated from the transmission system operations and maintenance segment. Those two categories are equal to approximately $32 million in GDP (see Figure 9).

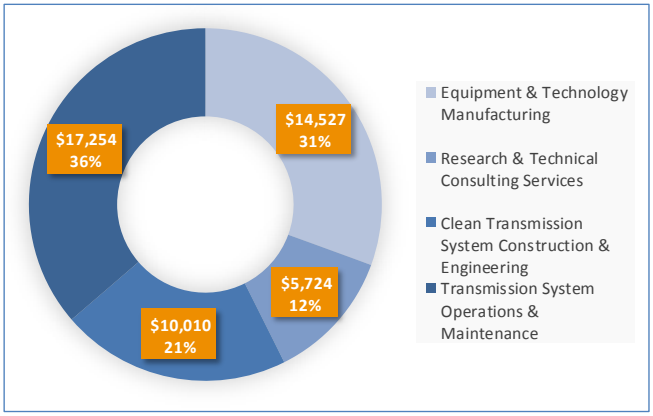


Source: The Delphi Group

Figure 8 - Direct jobs in Edmonton's Energy Storage & Grid Infrastructure sub-sector in 2016.

Projects & Activities

Alberta's announcement to phase out coal generation by 2030 will lead to a large transformation of assets and generation types operating on the inter-connected electricity grid. In parallel with the shutdown of coal generation, the Alberta Government's decision to add 5,000 MW of renewable electricity by 2030 will mean great care must be taken to ensure that grid reliability is maintained despite the introduction of a large capacity of largely intermittent renewable electricity. Layered on top of these policy changes is a growing population and asset base requiring electricity. At the nexus of all these changes are systems that can intelligently and seamlessly ensure that sufficient power is generated, transmitted, and distributed to customers on demand. Energy storage and smart grid technologies are at the forefront of this transition and Edmonton is well-positioned to take advantage of this shift.



Source: The Delphi Group

Figure 9 - Direct GDP from Edmonton's Energy Storage & Grid Infrastructure sub-sector in 2016 ($ thousands).

Transmission & Distribution

Alberta's electricity grid covers significant distance across the province, linking disparate generating assets to consumer demand in cities and rural areas. Alberta's grid can be thought of in two components: (1) a very high or high voltage transmission network that spans long distances, and (2) a lower voltage distribution system that is found closer to the end user. Both parts play critical roles in the delivery of electricity to Edmontonians. As greater amounts of intermittent electricity sources are added to the interconnected grid out to 2030, the need for transmission upgrades to ensure connectivity and uninterrupted service delivery will be needed.

Alberta's vast transmission and distribution network spans 26,000 km of transmission lines, connecting 235 generating units on the open market. Unlike electricity production, for the most part transmission is a monopoly service in Alberta, which means there are only a few wire providers in the province and each provider has their own geographic region of authority. The Alberta Electricity

[37] Comparatively, for this subsector the Calgary CMA has 471 direct jobs an $67 million in direct GDP in 2016.

System Operator (AESO) manages the transmission system by conducting regular transmission planning to ensure that there will be sufficient infrastructure to meet future demand.

With the increase in decentralized energy systems, transmission and smart grid planning will be a critical challenge for the AESO moving forward. Flexible smart grid and energy storage options can help play a key role in ensuring transmission costs stay low for Albertans.

Alberta is divided into 42 transmission planning areas, including one region specifically devoted to Edmonton and surrounding area. Three transmission companies have been granted a monopoly to provide transmission and distribution services to Edmonton and the surrounding area. These are Altalink, ATCO, and EPCOR.

EPCOR is the local transmission and distribution utility services company in Edmonton. EPCOR is owned by the City of Edmonton and has 260 kilometres of transmission wires, 5,500 kilometres of distribution lines, and a total offering of transmission services to 370,000 sites.[38]

Currently, there are 12 ongoing transmission projects in the Edmonton transmission planning area.[39] Ongoing transmission line projects include:

- Transmission system development in the South and West of Edmonton – to respond to the growing demand for electricity from residential, commercial, and industrial growth;
- Capital Power Energy Centre Connection – transmission access for Genesee Generating Station, Units 4 and 5;
- Numerous substation upgrades and modifications; and
- The West Edmonton Transmission Upgrade Project.

Alberta's micro-generation regulation will help reduce transmission congestion and demand but will also create challenges for wire providers. Micro-generation enables Albertans to install an electricity generating unit up to 5 MW in size and connect the generating asset to the distribution component of the electricity grid. Electricity generation must exclusively use sources of renewable or alternative energy (such as solar PV, small-scale hydro, wind, biomass, geothermal, and fuel cells), and system capacity must be structured to meet the needs of homeowners or businesses and cannot be built for the sole intent of selling electricity back to the grid through net metering. Transmission companies that own the distribution network (e.g., EPCOR) are obliged to connect micro-generation customers into the system.

According to QUEST Canada, "one of the most touted approaches to enhancing the resilience of energy distribution infrastructure is by integrating micro-grids, distributed generation, and storage opportunities into more traditional, centralized electricity and natural gas distribution grids. These approaches often require collaboration among distributors, local governments, provincial governments, property owners, and private stakeholders."[40]

Through decentralized generation, overall peak demand on transmission lines should be reduced, and consequently upgrades and new infrastructure costs could be deferred to a later date. However, the challenge with micro-generation is the injection of electricity onto the distribution network. The distribution network was primarily designed to deliver electricity, and not to accept electricity from numerous generation devices. This creates the challenge of ensuring that the distribution network has sufficient infrastructure to handle multiple solar or wind providers providing electricity at the same time back onto the grid. To mitigate any challenges, smart grid investment is needed. Since the distribution network is at the community level, Edmonton can capture the investment and jobs needed as upgrades are made to the EPCOR network. The need to monitor, manage, and upgrade the transmission and distribution network to ensure that Edmontonians have a reliable system will only increase in the coming decade as electricity systems are transformed by a push to integrate renewables, energy storage, and energy efficiency.

[38] https://www.epcor.com/about/Documents/EPCOR-investor-presentation-April2016.pdf

[39] https://www.aeso.ca/grid/projects/

[40] QUEST Canada "Resilient Pipes and Wires" report (2015). See: http://www.questcanada.org/events-projects/research/rpw

Smart Grid Applications & Energy Management Solutions

With an increasing proliferation of intermittent electricity sources, a desire for net metering, energy efficiency, and projections of a larger number of micro-grid installations being constructed over the next decade, there is a need for equipment, software, and systems that can manage these changes to the electricity system. Smart grids rely on data to ensure proper decisions are made. Utilities and transmission providers are upgrading infrastructure to collect better data and enable intelligent software to better manage the electricity system.

Both Altalink and ATCO have, in recent years, installed technology such as phasor measurement units, dynamic thermal line ratings, or static VAR compensators to enhance the intelligence of their grids to enable them to respond better when challenges arise.

EPCOR has been on the leading edge, preparing the distribution network in and around Edmonton for the different technologies that will integrate with the grid in the future including EVs, energy storage, or energy efficiency products.

EPCOR also recently upgraded over 385,000 electricity meters in Edmonton and surrounding area to "smart" meters. The smart meters will use radio frequency emissions to provide EPCOR more accurate electricity use information, as well as statistics on the quality of electricity and rapidly inform operators of the location of outages. Smart meters can also help utilities plan for upgrades and improvements. An example of this is that smart meters can readily identify the presence of an EV based on the demand curve of the user. If the utility, through smart meters, notices that a number of sites in a localized distribution network are plugging in EVs on a regular basis, the utility can respond by planning upgrades or shifting the amount of electricity available to ensure that there are no outages and that supply is not compromised. This scenario will become more common as the uptake of EVs and other distributed energy technologies increases in Edmonton.

Interest is also growing in Edmonton for micro-grids. One example is a combined heat and power borehole thermal energy storage micro-grid project that is part of the redevelopment of the Southwoods 19-acre site in southeast Edmonton.[41] These smaller grids help create resilience in the overall electricity system and for the communities they service.

In addition, ongoing research at the University of Alberta is exploring the impact that smart cars, electric vehicles (EVs), energy storage, solar photovoltaics and more will have on the distribution network in the coming years. This research will help stakeholders in Edmonton prepare more effectively for the coming changes.

Edmonton companies involved in the smart grid and power management space include SUBNET Solutions Inc., and DX3 Enterprises. SUBNET Solutions Inc. focuses on software products for the electrical utilities industry, specifically, software for substations and power systems to create a more intelligent power grid. DX3 Enterprises has developed an 'anti-islanding' protection system, which allows for the interconnection of Distributed Generators (DGs) to the utility power grid.[42] Despite the activity in this space, there is currently not an established critical mass of companies within Edmonton providing smart grid technologies.

Energy Storage Technologies

Energy storage is an emerging, disruptive technology that will transform how power is delivered to Albertans. Energy storage is a unique, multi-use technology that can impact customers and utilities in different ways as depicted in Figure 10.

Many different energy storage technologies exist, including:

- Flywheels
- Solid state batteries (electrochemical capacitators, lithium-ion, nickel-cadmium, sodium sulfur)
- Lead acid batteries
- Flow batteries
- Compressed air energy storage (CAES)
- Pumped hydro
- Thermal energy
- Fuel production (e.g., hydrogen, methanol, etc.)

[41] See: https://gssenergy.ca/?portfolio=lorem-ipsum

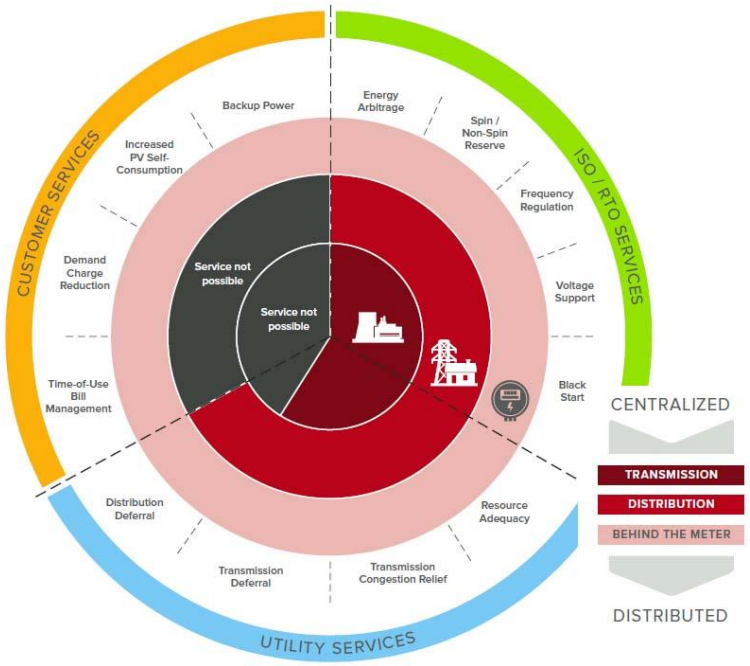
[42] See: http://www.dx3ltd.com/

Different storage technologies can serve a different functions and store energy for varying time frames, providing flexibility to end users depending on needs. There are opportunities for Edmonton energy storage companies to provide value primarily for customer services, although as the AESO regulations are established, utility and ISO services may emerge as opportunities as well.

For example, Edmonton businesses could potentially use energy storage products to reduce their peak demand, which could help them realize cost savings.

In Alberta, it is technically feasible for an energy storage unit to provide a combination of price arbitrage, ancillary services, and time shifting. This is an example of "stacking" energy storage services. According to Alberta's Department of Economic Development and Trade, stacking remains a key opportunity in the Alberta market.[43]

Under the existing policy regime, however, an energy storage device must pay each time it is charged and each time it is discharged – paying twice, while all other electricity grid participants only pay either a charge or discharge fee. This is one major hurdle to the introduction of energy storage devices on the Alberta Electricity System. Tariffs and rate treatment for energy storage facilities are currently being examined by the Alberta Electricity System Operator. Once the AESO establishes the rules and regulations for energy storage systems, it is expected that projects will be able to move forward.



Source: RMI Economics of Battery Energy Storage report, 2015

Figure 10 - Multiple uses for energy storage technologies.

The AESO's position does not prevent energy storage from being installed on systems that are not connected to the electricity grid, or so called "behind-the-fence" systems. These are the type of systems that homeowners could install to complement their renewable energy systems to store power for later use.

Edmonton's green energy economy has private sector activity on battery systems. Companies in this space include Canadian Energy, Battery World, DC Solutions, Adven Industries, and Grengine.

Research work into electro-chemistry based energy storage related to lithium ion batteries and capacitors is ongoing at the UofA.

The Energy Systems Research Group at the UofA, within the Department of Electrical and Computer Engineering, includes nine researchers from the Faculty of Engineering who are focused on distributed generation and micro-grids, smart grids, electric energy storage, power electronics, and real-time simulation of large-scale power systems (see sidebar).[44]

The UoA has also partnered with NAIT to develop a distributed energy management / smart grid demonstration lab which will be commissioned soon. Courses are also now being offered at NAIT in energy storage and fuel cell technologies.

[43] Invest Alberta, Ministry of Economic Development & Trade "Energy Storage Markets in Alberta: Opportunities & Challenges" report (Aug. 2016).
[44] See: http://ece.engineering.ualberta.ca/en/Research/EnergySystems.aspx

The University of Alberta Energy Systems Research Program is a group of nine researchers that are focused on all aspects of the energy system from generation, transmission, distribution, and utilization of electrical energy. Research interests cover a wide range of topics including:

- distributed generation and microgrids
- smart grids
- renewable energy includes PV, wind and biogas systems
- electric energy storage
- electric and hybrid electric vehicles
- power electronics topologies, control and PWM techniques
- power electronics for renewable energy interfaces
- computational electromagnetism
- power quality
- power system signaling, monitoring and measurements
- real-time simulation of large-scale power electric and power electronic systems
- industrial, commercial and utility system reliability
- power system stability
- power system operation and control

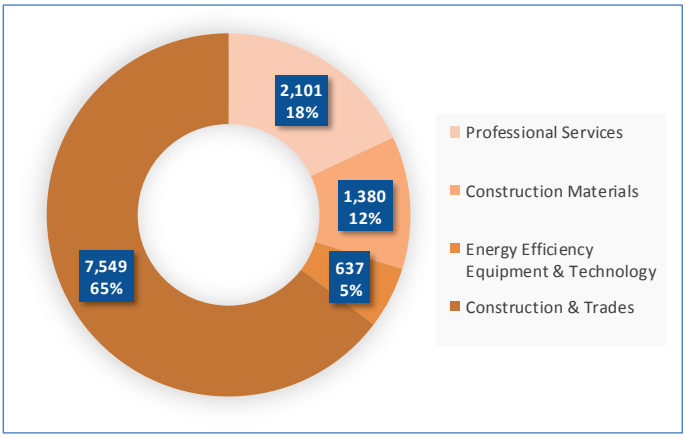
See: http://ece.engineering.ualberta.ca/en/Research/EnergySystems.aspx

Green Building & Energy Efficiency

Jobs & GDP

The Green Building and Energy Efficiency sub-sector is the largest employer and revenue generator for Edmonton's green energy economy.

In 2016, Edmonton's Green Building and Energy Efficiency sub-sector was responsible for approximately **11,670 direct jobs** and **$1.36 billion** in direct GDP across the value chain, corresponding to 1.6% of Edmonton's workforce.[45]



Source: The Delphi Group

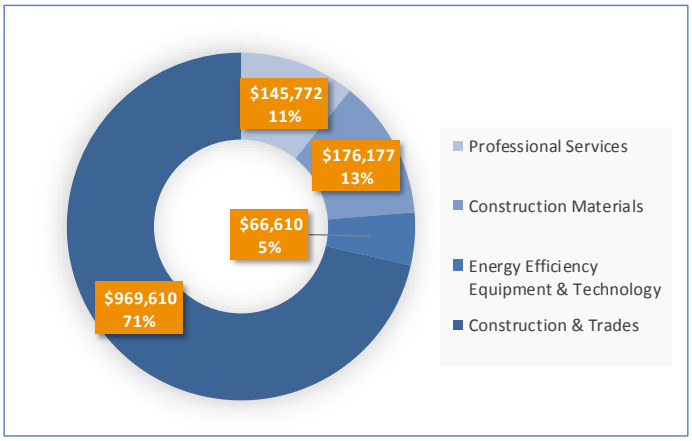
Figure 11 - Direct jobs in Edmonton's Green Building & Energy Efficiency sub-sector in 2016.

As illustrated in Figure 11, employment was highest in the construction and trades (which includes work on green building related projects only), equal to 7,549 jobs or 65% of all employment in this sub-sector. The next largest segment is professional services (which include jobs in architecture, design, and engineering, as well as property management, equipment repair and maintenance, research, and technical services), equal to 2,101 jobs (or 18% of all employment in this sub-sector). Edmonton also has a healthy construction materials manufacturing segment with 1,380 jobs directly related to green building materials. Energy efficiency technology and equipment was the smallest segment in 2017.

Almost $970 million dollars in GDP is derived from the strong construction and trades sector in Edmonton. Construction materials contributed $176 million to provincial GDP in 2016, while professional services provided $146 million (see Figure 12).

Projects & Activities

There have been marked changes to Alberta's Green Building and Energy Efficiency sub-sector over the last two decades. This is in part due to the evolution of the sub-sector on the global stage, which has begun to prioritize outcomes through good urban design, such as health and wellness and employee productivity, in addition to conventional environmental and energy outcomes. Two primary drivers are responsible for the uptake in green buildings and improved energy efficiency: (1) policy and regulation, and (2) economic benefits associated with owning and operating green buildings, where the latter have become increasingly influential in transforming the market.



Source: The Delphi Group

Figure 12 - Direct GDP from Edmonton's Green Building & Energy Efficiency sub-sector in 2016 ($ thousands).

[45] Comparatively, this sub-sector contributed 11,162 direct jobs and $1.26 billion in direct GDP in 2016, corresponding to 1.4% of Calgary's workforce.

Residential Buildings

Approximately one-fifth of Edmonton's energy use and associated GHG emissions in 2012 were from residential energy consumption.[46] This is not surprising, given Edmonton's cold climate and the energy demand to maintain heating and lighting during the long, dark winter months in central Alberta. But this illustrates an opportunity for solutions to help reduce that energy demand. In November 2016, the Government of Alberta modified its energy efficiency standards for building construction codes to be aligned with Alberta's Climate Change Strategy, which may further improve the average home energy consumption within Edmonton.[47]

Edmonton has been a leader in Canada in terms of Built Green certifications. Within Alberta, Edmonton certified 44% of all provincial Built Green homes from 2013 to 2016 and currently has the highest number of Built Green homebuilder firms in the province (30 builders). Additionally, Edmonton has shown a commitment to improving energy efficiency awareness within the residential sector by launching the "Spot the Difference" Program, which offers EnerGuide evaluation rebates to homeowners in exchange for sharing their energy rating on an online, publicly available map.[48]

Other residential green building certifications such as ENERGY STAR, LEED for Homes, and Passive House have had limited uptake in Edmonton to date, likely due to the fact that they are relatively newer programs to Alberta and education will be needed to increase public awareness.

One area of particular strength for Edmonton is designing and building net zero energy (NZE) homes. NZE homes offer benefits such as low annual operating costs, stable energy costs for future years, well-insulated building envelopes that make homes more comfortable year-round, and excellent indoor air quality. According to the Canada Mortgage and Housing Corporation (CMHC), "a net-zero energy house is designed and built to reduce household energy needs to a minimum and includes on-site renewable energy systems, so that the house may produce as much energy as it consumes on a yearly basis." NZE homes are optimized for maximum energy efficiency, often implementing passive house design features focused on the building envelope first.

The first NZE home built in Edmonton was completed in 2009. Since then, an estimated 70 NZE homes have been built throughout the city.[49]One example is the Riverdale NetZero Project,[50] a duplex that was built with a solar PV array, solar hot water heating, air tight building envelope, and locally sourced construction materials. The home uses 60% less indoor potable water, has passive solar heating, energy efficient windows, and produces very low to no greenhouse gas emissions. The Riverdale NetZero home is an excellent example of what is possible for green building in Edmonton. Furthermore, data and learnings from the build are readily available to the public and can be used to help inform other builds, so that the public can benefit. For example, the Mill Creek NetZero home benefitted from the knowledge gained by the Riverdale construction, and the builders were able to save time and money.[51]

The development of NZE homes has been driven not by public policy but the private sector. Alberta has also been at the forefront of the NZE push in Canada, with builders such as Habitat Studios, Effect Home Builders, DeWaal Builders, and Landmark Homes.

Local homebuilder Landmark Homes has been active on the NZE home development in recent years and has built 20 NZE homes in Calgary and Edmonton. The advancement of building best-practices and the decreasing price of solar PV technology, are making NZE homes increasingly cost competitive with traditional homes. In early 2017, Landmark announced affordable NZE homes with a starting price of just under $400,000, which is in line with the median home price for a single-family home in Edmonton of ~$391,000.[52] Located in the Maple Crest community of Edmonton, these three demonstration homes will add to the total in Alberta, and the show homes will help with public awareness and education. Additional NZE homes are planned.[53]

[46] See: https://www.edmonton.ca/city_government/documents/EnergyTransitionStrategy.pdf

[47] The new National Energy Code for Buildings 2011 and the Energy Efficiency requirements of Section 9.36 of the Alberta Building Code 2014 have become minimum standards for construction permits in Edmonton. See: https://www.edmonton.ca/residential_neighbourhoods/permits_licences/energy-code-requirements.aspx

[48] See: http://ace.edmonton.ca/energuide/

[49] Estimate provided by Habitat Studio employee. The estimate counts individual units from multi-dwelling properties.

[50] See: https://www.cmhc-schl.gc.ca/en/inpr/su/eqho/rinezepr/rinezepr_003.cfm

[51] See: http://greenedmonton.ca/MillCreekNetZeroHome.html

[52] See: https://www.newswire.ca/news-releases/net-zero-homes-priced-under-400000-have-arrived-in-edmonton-616626364.html

[53] See: https://landmarkhomes.ca/blog/category/media-release/

Non-Residential Buildings

Large / commercial buildings consumed more of Edmonton's total energy demand than residential buildings (23% versus 19%) in 2012 but were responsible for the same share of Edmonton's total GHG emissions in 2010 (both 19%).[54]

Green building certification for commercial and institutional sector facilities are offered through the Building Owners and Managers Association (BOMA) Building Environmental Standards (BEST) program for existing buildings and the Canada Green Building Council's (CaGBC) LEED program for both new construction and existing buildings.

From 2013 to 2015, the percentage of total commercial floor space in Alberta that is LEED certified grew year-over-year before dropping off slightly in 2016. Table 4 shows the historical penetration rate of LEED certified buildings as a percentage of total commercial floor space in Alberta (27% in 2016). As of 2016, Alberta had the highest area of certified LEED floor space per capita in Canada.[55]

By the end of January 2018, there were 113 LEED certified projects in Edmonton, covering 1.9 million m^2, comprising approximately 24% of all LEED certified floor space and 23% of the 493 LEED certified projects in Alberta. CaGBC recognized the City of Edmonton as a 2016 industry champion for certifying five LEED projects within that year.[56]

Table 4 - Market penetration of certified LEED floor space as a percentage of total new commercial and institutional floor space by year.

	2012	2013	2014	2015	2016
Total Commercial / Institutional Floor Space - Alberta (million m2)	108.5	110.9	113.4	115.7	118.0
Year on Year % Change - new construction	1.6	2.4	2.5	2.3	2.3
3 Year Rolling Average % Change - new construction	1.8	1.8	2.2	2.4	2.4
LEED Certified Floorspace (million m^2)	0.40	0.86	0.74	0.64	0.52
3 Year Rolling Average % Change - LEED Certification (million m^2)		0.52	0.67	0.75	0.63
LEED as % of Total Commercial/Institutional (3 year rolling average)			30.8%	31.3%	26.9%

Source: The Delphi Group using data from CaGBC and Natural Resources Canada

Within LEED, seven of the 109 Edmonton projects were certified within its Existing Buildings: Operations and Maintenance (EB:OM) rating system. Participation within the BOMA BEST program, which certifies buildings on energy and environmental performance standards specifically for existing buildings, has increased in Edmonton from its first and only certification in 2013 to 92 certifications in 2016.[57]

Edmonton's percentage of commercial LEED buildings as a provincial total is comparatively lower than Calgary, at approximately 65% of all LEED floor space and 48% of the LEED certified projects, in part due to the relatively slower pace of downtown office tower construction.

However, numerous LEED projects have been recently certified or are in the process of being built. Notable mentions include the Royal Alberta Museum (anticipated Gold), Stantec Tower (anticipated Gold), EPCOR Tower (Silver), Rogers Place (Silver), Edmonton Tower (anticipated Gold), and the Brewery District (anticipated Silver). Outside of downtown core, buildings such as the priMED Mosaic Centre (certified as LEED Platinum), Center for Applied Technology at NAIT (certified as LEED Gold) and the Donadeo Innovation Centre for Engineering (certified as LEED Gold) further demonstrate the trend of LEED building in the commercial and institutional space.

[54] A higher proportion of commercial building GHG emissions were sourced from natural gas instead of electricity when compared to residential buildings. Natural gas is a more efficient source of energy than electricity within Alberta, which explains how energy consumption can be higher for commercial buildings but emissions can still be the same as residential buildings. For energy consumption and GHG emission share percentages see: https://www.edmonton.ca/city_government/documents/EnergyTransitionStrategy.pdf

[55] Calculated from Canada Green Building Council 2016 Annual Report. See: https://www.cagbc.org/cagbcdocs/aboutcagbc/CaGBC_2016AR_ENG.pdf

[56] Canada Green Building Council 2016 Annual Report. See: https://www.cagbc.org/cagbcdocs/aboutcagbc/CaGBC_2016AR_ENG.pdf

[57] BOMA BEST certification data for only part of 2017 was available and was therefore excluded, but they appear to have dropped of significantly from 2016 (24 certified projects, as of December 2017) unless there is a time delay in updating this data.

Leadership initiatives from the City of Edmonton have been outlined in the 2017 Sustainable Building Policy, which mandates that certain existing city-owned buildings participate in the BOMA BEST certification program and the City of Edmonton Large Building Energy Reporting and Disclosure Program [58] The reporting and disclosure program, launched in 2017, will track energy efficient indicators from buildings larger than 20,000 square feet with incentives offered to private building owners in order to encourage their participation.[59]

Building Retrofits

The rapid growth in the quality and energy performance of new buildings are an important step to greening Edmonton's building infrastructure; however, low building replacement rates mean that new builds are only a small part of the solution. [60] The Harvard Business Review has identified old buildings to be the biggest sustainability challenge in U.S. cities where the vast majority of current, less energy efficient, buildings will still be in place by 2030.[61]

With many buildings in Edmonton falling into the 30-35 year range, there is a large opportunity for retrofitting. However, retrofits can be complex and expertise may be limited amongst Edmonton's current building professionals, requiring a learning curve to grow experience with retrofits. Programs offered through Energy Efficiency Alberta can help grow expertise by providing building owners financial incentives to complete renovations or install energy efficient products.[62] In 2017, approximately $3.5 million in incentives were delivered to Albertans for thermostats, washing machines, refrigerators, and light bulbs.

Source: www.primedmosaiccentre.com

The priMED Mosaic Centre is a net-zero energy commercial building located in south Edmonton's Summerside neighbourhood. It is owned by priMED Medical Products. Construction was completed in 2015 and the project achieved LEED Platinum certification in 2017. The centre was originally conceptualized and owned by entrepreneurs Christy and Dennis Cuku, who wanted to create an ideal workspace that is sustainable, beautiful, and affordable. The building was later sold to priMED who stewards Christy and Dennis' original vision and is committed to providing a positive, healthy and engaging culture for its tenants, neighbouring business and the local community.

Highlights include:

- The world's northernmost net-zero energy commercial building
- Powered by a 213 kW photovoltaic panel array
- Heated and cooled by 32 geothermal wells
- Built using the Integrated Project Delivery (IPD) process – a collaborative approach between individual participants – consultants, engineers and contractors – during building design, fabrication and construction phases to reduce project waste and maximize efficiency
- Constructed with a wood structure allowed the builders to avoid 930 tons of GHG emissions
- Electrical vehicle charging stations
- Located near bicycle paths and trails with secure indoor bike parking to encourage tenants to bike or walk to work
- A rainwater collection system to provide nearly 100% of the water required for onsite landscaping
- Tenants have signed "green leases" requiring them to take measures to reduce energy and water usage, conduct business in an environmentally friendly way, and to source sustainable materials when completing leasehold improvements.

[58] See Sustainable Building Policy (Policy Number C532): https://www.edmonton.ca/city_government/documents/PoliciesDirectives/C532.pdf

[59] See: https://www.edmonton.ca/programs_services/environmental/building-energy-benchmarking-program.aspx

[60] Historical building replacement rates in the US have been about 2%. See: https://www.usgbc.org/articles/existing-buildings-99

[61] See: https://hbr.org/2016/01/old-buildings-are-u-s-cities-biggest-sustainability-challenge

[62] During its first year of operation, EEA provided approximately $3.5 million in incentives to 1,200 businesses, non-profits, and institutions. See: https://www.efficiencyalberta.ca/app/uploads/INFOGRAPHIC-2017-Year-in-Review.pdf

Community-Scale Projects

Two large urban development's currently underway or planned within Edmonton's city limits which have embraced green buildings and energy efficiency include: the region surrounding the ICE District and the Blatchford redevelopment project.

The mixed-use residential and commercial area along 104 Avenue from 97 to 121 Street NW (3 kilometre span) in central Edmonton has undergone extensive development over the past five years, with the most drastic changes emanating from the ICE District, a 25-acre mixed-use sports and entertainment district. The region consists of high density residential, commercial, and retail space that is designed to improve walkability and access to public transportation.

Blatchford is an anticipated sustainable mixed-use residential and commercial redevelopment on former City Centre Airport lands. Blatchford is expected to be home to up to 30,000 residents by 2030 with 100% of its energy needs met by renewable sources. It is anticipated to be one of the first carbon-neutral communities in Canada. This will require that buildings incorporate low-flow fixtures, efficient lighting and appliances, improved insulation and windows, and even rainwater capture systems which go beyond Alberta building code. The proposed community is located approximately 4 kilometers north of Edmonton's city centre, covering 536 acres.

Construction commenced in 2017 after being delayed by an extra year with alterations to original architectural plans, but Blatchford is still expected to integrate innovative energy and waste reduction features, such as: a geo-exchange system to store heat energy, a sewer heat exchange and district energy sharing system, a renewable energy utility, reuse and recycling initiatives of airport materials, and urban design for improved walkability and public transit use. Environmental impacts from all phases of the Blatchford redevelopment project will be mitigated where possible.

These developments serve to transform Edmonton's downtown, and require significant collaboration with the City, different levels of government, investors, urban planners, developers, owners, and tenants. They are a testament to Edmonton's ability to show leadership in building sustainable communities that are supported by green buildings and a commitment to energy efficiency.

Professional Services

Professional Services for Green Building and Energy Efficiency includes firms involved in architecture and design, engineering, property management, equipment maintenance and repair, and a range of more technical services such as energy auditors and modelers.

When professional services collaborate, they are able to streamline processes, reduce waste, and improve efficiency over a building's lifecycle, which includes its design, engineering, construction, and operation phases. Extensive collaboration is often required to achieve LEED Platinum certification, the highest rating of the LEED standard, two of which are found in Edmonton: PriMED's Mosaic Centre and the Habitat for Humanity Net Zero Precast Concrete Home.

The collaborative nature of green building design has gained momentum internationally, where competition is fierce and even minor efficiencies present an advantage. Emerging integration tools, such as Building Information Modelling (BIM), Building Management Systems (BMS), and off-site construction or pre-fabrication, help coordinate efforts from multiple participants when engaging on a project. The traditional 'design-bid-build' model, where each participant focuses exclusively on their own construction tasks, is increasingly viewed as obsolete when compared to the 'integrated project delivery' (IPD) model, which focuses participant efforts through collaborative incentives, for green building. The shift towards collaborative technologies and processes helps to reduce waste, increase cost savings, and improve productivity.

BIM software integrates 3D modelling with project management, facilitating the coordination and communication of the design-construction-operation teams for a building under one platform. For example, BIM can be used to meticulously plan construction schedules and site utilization so that participants can identify potential problems before starting construction. During the operation

phase, BIM can be used to calculate the energy savings of proposed renovations, such as window replacements. Many architecture and design firms use BIM platforms and IPD models to meet their client needs.

Full service, integrated architecture, design, and engineering firms operating in Edmonton's commercial and institutional high-performance building sector include Stantec, and Kasian Architecture. Consulting firms in Edmonton offer technical services such as mechanical and electrical system upgrades, energy and water audits, and energy management and planning operator training, as well as support to building developers interested in achieving green building certifications. Companies in this consulting space include EcoAmmo, Manasc Isaac Architects, DIALOG Design, and 3D Energy.

Commercial, institutional, and high-rise residential building owners and managers in Edmonton are recognizing that operating high-performing buildings reduces operating costs by improving energy efficiency and attracts and retains tenants. Bentall Kennedy, Humford Management, One Properties, and QuadReal, are major players in this space in Edmonton.

Stantec Tower (pictured) will be the new local headquarters for Stantec Consulting Ltd, a professional services company in design and consulting. Since being founded in 1954, Stantec has spread to three different continents and has constructed thousands of buildings, many of which incorporate elements of sustainable design. Stantec takes an integrated approach to building design and construction that considers climate and site, performance modeling, passive and net-zero design, WELL Building criteria, LEED certification, and post-occupancy assessments.

At 66 stories, Stantec Tower will be the tallest building in Edmonton, transforming the city's landscape. Stantec Tower is LEED Gold registered and is expected to be complete in 2018.

For more information, see: https://www.stantec.com/en/services/sustainability-building-performance/about-sustainability-building-performance

Construction & Trades

The construction and trades segment is the largest in terms of the number of jobs and consists of general contractors, builders, and relevant trades such as foundational and structural contractors (e.g., carpenters), building equipment contractors (e.g., electricians, heating, and plumbing contractors), finishing contractors (e.g., drywallers, floor installers, and painters), and other specialty trades (e.g., solar PV installers). These professionals, just by their numbers, can have a significant impact and influence on the introduction of green building and energy efficiency products.

Construction companies and tradespeople in Edmonton with experience in green building and energy efficiency are still somewhat limited but growing. Energy efficiency is become more commonplace in construction discussions as consumers are looking for ways to reduce their electricity and heating bills. As customers continue to demand more energy efficient and green building products, construction companies and the trades will become more well versed and comfortable with their installation and use.

Companies such as ART Custom Homes, Bedrock Homes, Green Living Homes, Landmark Homes, Brookfield Residential, Homes by Avi, Kanvi Homes, Novhaus, and Jayman BUILT are BuiltGreen builders in the Edmonton area, designing and building homes that are more sustainable and energy efficient.

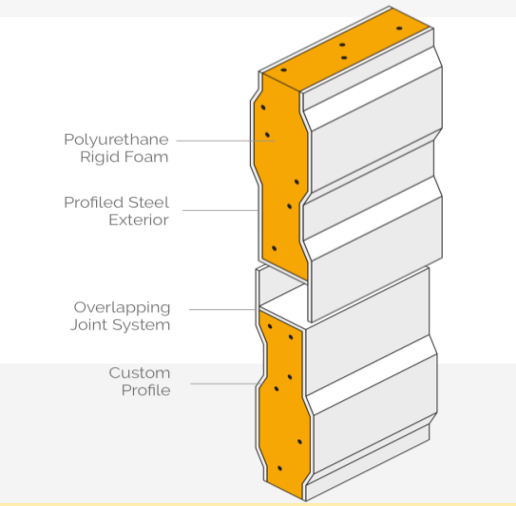
Edmonton is also a leader in pre-fabrication and modular construction, with companies such as Landmark Homes, ACQBuilt, Novhaus, and Honomobo advancing this construction approach. Novhaus and Honomobo offer pre-fabricated, modularized shipping container homes and garage suites. In 2015, Landmark Homes contributed $10 million to the University of Alberta Faculty of Engineering to focus on improving the construction and design of materials and energy use for homes and commercial buildings. Both Landmark Homes and ACQBuilt offer modular home construction with homes being built at their facilities then shipped to site for efficient construction.

Green Building Materials, Equipment & Energy Efficient Technologies

Manufacturing of building materials and products is one of Edmonton's strengths and this translates to the green building materials value chain. Green building products and materials touch all parts of the construction value chain including insulation, wall panels, doors, cement, lumber products, and modular houses, and demand has been growing as green buildings and certifications have become the norm. For example, more stringent LEED Certifications show preference to sustainably grown, locally harvested, biodegradable materials. Edmonton is able to source many of these materials through regional suppliers with some local manufacturing for windows, lighting, wall assemblies, and insulation (e.g., Enerpan is an Edmonton based-business that creates high performance building panels).

In the lighting space, Edmonton is home to manufacturers and suppliers of LED lighting solutions. LED Smart manufactures LED lighting solutions for military, industrial, transport, and commercial applications. Companies such as Design 21 LED and Commercial Lighting Products distribute energy efficient lighting options for commercial and residential uses.

The City of Edmonton has also initiated a program to replace its street lighting from less efficient, sodium vapour lamps to LED luminaries. In 2010, Edmonton engaged EPCOR to test six different LED street light luminaries to identify and implement an energy efficient, low maintenance solution for its roads. The city began replacing residential street lights in 2011 along with lighting bases and underground cabling for poles that are nearing the end of their life. The new lamps are expected to save 40% in energy costs and GHG emissions. About 27,000 of the City's 120,000 street lights had been replaced as of December 2017, with the goal of converting the remaining street lights within the next five years.[63]



Enerpan offers structural insulated panels (SIPs) for industrial, commercial, and residential construction. Enerpan's SIPs consist of an insulated foam core sandwiched between two structural facings which can reduce construction supplies such as structural framing, vapour barriers, gypsum and sheeting and installation time due to their easy to install manufactured joint system. The panel insulation improves energy efficiency, reducing building heating costs, and can be made flame-resistant.

For more information, see: http://enerpan.com/

Energy efficient household appliances have followed a similar growth trend to that of green building. The market share of certified ENERGY STAR appliances shipped in the Prairies region has consistently risen over the past decade except for 2015, the last year of reported sales data. It is suspected that the decrease in energy efficient appliance sales is a result of the recent economic downturn.

Buildings are becoming more efficient and "smart" through the adoption of new technology, in particular, those that integrate with controls and automation systems, which offer customers potentially significant energy and cost savings. Companies such as Solution 105 offer analytical services to help track energy management and improve energy efficiency. Others such as NuEnergy offer technical solutions to track energy management. Operators are quickly adapting to a new world of building integrated management systems and the shift will only become more prevalent as technology continues to advance and implementation costs decrease.

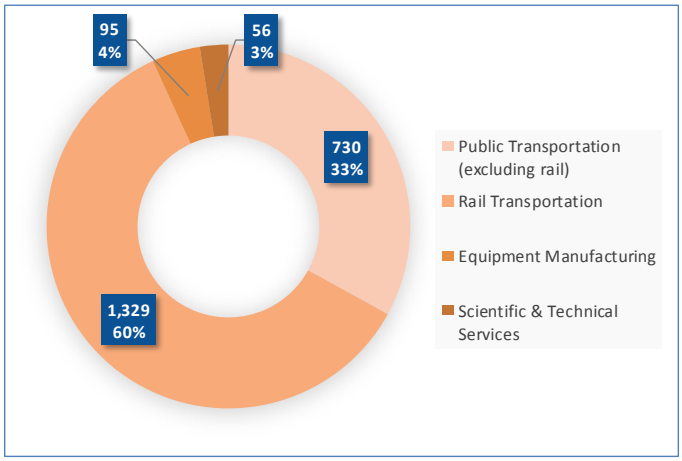
[63] See: https://data.edmonton.ca/Transportation/LED-Streetlight-Conversion/rxke-mcvd

Green Transportation

Jobs & GDP

Edmonton's Green Transportation sub-sector was responsible for approximately **2,210 direct jobs** and **$307 million in direct GDP** across the value chain in 2016, corresponding to 0.3% of Edmonton's workforce.[64] As illustrated in Figure 13, the rail transport segment is the highest source of employment within this subsector, consisting of approximately 1,329 jobs or 60% of all jobs in the Green Transportation subsector. Public transportation (excluding rail) was the second largest employer, with 730 jobs or a third (33%) of all subsector positions.

The rail transportation segment generated 75% of total subsector GDP, equal to nearly $230 million in 2016.



Source: The Delphi Group

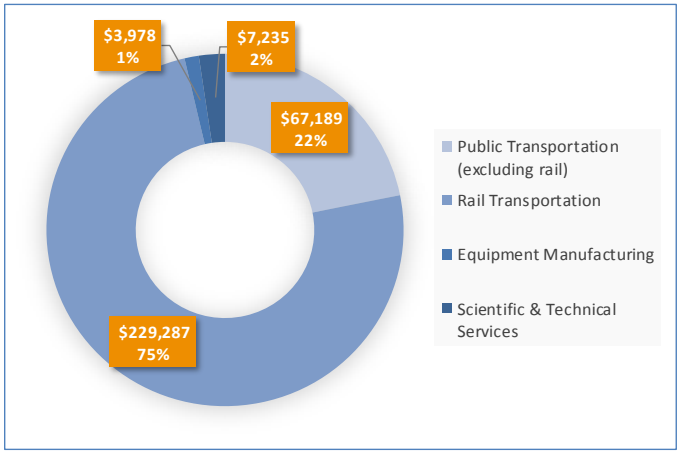
Figure 13 - Direct jobs in Edmonton's Green Transportation sub-sector in 2016.

Projects & Activities

Rail & Public Transit

The public transport and rail segments are responsible for over 90% of the Edmonton region's Green Transportation jobs, much of which is supported by the movement of large numbers of people and volumes of goods via Edmonton's rail and transit networks.

Edmonton's industrial parks, the Edmonton International Airport, the Alberta Industrial Heartland, and the Leduc-Nisku Business Park (Canada's largest and North America's second largest energy park) are major goods generators for the region [65] From a green transportation perspective, rail transport has the advantage of significantly reducing fuel consumption and GHG emissions when compared to transport by truck. Edmonton provides rail transportation through two intermodal facilities, the Canadian National (CN) Railway and Canadian Pacific (CP) Railway yards. However, Edmonton also transports many of its goods via truck, due to being situated at the junction of two large highway corridors, the Yellowhead Highway (the northern Trans-Canada) and Queen Elizabeth II Highway (part of the CANAMEX corridor linking Canada, the United States, and Mexico).



Source: The Delphi Group

Figure 14 - Direct GDP from Edmonton's Green Transport Sub-sector in 2016.

Edmonton's public transit enjoys one of the busiest light rail transit (LRT) riderships in North America (eighth highest) as of 2014. Recent and planned investments will further enhance public transit in the Edmonton region, some of which include major public transit projects (outlined in Table 5) that are either operational, currently under construction, or proposed.

[64] Comparatively, for this sub-sector the Calgary CMA has 3,821 direct jobs and $493 million in direct GDP in 2016, corresponding to 0.4% of Calgary's workforce.

[65] See: https://www.edmonton.ca/city_government/documents/PDF/CoE_GMS_Report_2014_CR_931_WEB.pdf

Table 5 - Recent and future transit projects in Edmonton[66]

Project Name	Description	Status	Estimated Cost ($ Mil.)	Completion Year
Metro Line - North to NAIT	3.3 km extension from Churchill LRT Station in downtown Edmonton northwest to NAIT.	Operational	665	2014
Smart Bus Project	Equipped ETS buses with Smart Bus technology to provide real-time information to customers and ETS control.	Operational	20	2015
North East Transit Garage	500,000 sq. ft. to provide capacity for 300 buses and administrative and operational space.	Under Construction	186	2019
Valley LRT Line[1]	27 km low-floor urban line between southeast and west Edmonton.	Under Construction	3,600	2023 or later
Metro Line - NAIT to Campbell Road	Extension from NAIT LRT Station in northwest Edmonton to St. Albert.	Concept	Unknown	Unknown

[1] Cost estimate based on $1.8 billion budget for 13 km line of Valley Line West, representing roughly 50% of the total line length.

Source: City of Edmonton

The Way We Move Transportation Master Plan (TMP) is the City of Edmonton's 10-year plan for addressing its future transportation needs (2009-2018). The TMP outlines seven strategic goals that have been developed with a time horizon 30-years into the future. The seven TMP goals align with Edmonton's other strategic plans and include:

- Transportation and Land Use Integration Access and Mobility
- Transportation Mode Shift
- Sustainability
- Health and Safety
- Well-Maintained Infrastructure
- Economic Vitality

Source: http://www.look4edmontonhomes.com/lrt-homes.php

Photo caption: Edmonton Transit Services Light Rapid Transit system has the 8th highest ridership in North America.

In 2014, the City of Edmonton produced a report specifically addressing the transportation mode shift strategic goal to clarify its importance. Mode shift adds more active transport (walking and cycling), car-sharing, and transit to Edmonton's transportation mix, providing alternatives to using personal vehicles.

The City has taken a number of actions to promote mode shifting, including the approval of a 7.1km network of downtown bike lanes and LRT infrastructure expansions. A 2016 progress report on Edmonton's The Way Ahead strategic objectives indicated that transit ridership decreased in 2016.[67] This is consistent with another report published by the City documenting a decrease in utilization of the nine Edmonton Transit Service (ETS) park and ride locations around the city.[68] The decrease in transit ridership may be attributed to increased levels of unemployment in recent years. The City of Edmonton believes that ridership will increase after implementing planned initiatives such as bringing new LRT expansions online.

Public transit represents 70% of the 2015 to 2018 Capital Budget's transportation allocations (with the remaining 30% reserved for roads). Funding sources, such as the provincial Green Transit Incentives Program (GreenTRIP) and the federal Public Transit Infrastructure Fund (PTIF), provide support to critical infrastructure projects in Edmonton. These programs have resulted in the approval of nearly $225 million in funding for public transit projects in and around Edmonton since 2016.[69]

[66] See: https://www.edmonton.ca/projects_plans/transit.aspx

[67] Transit ridership is calculated by dividing the annual transit ridership by the city's population.

[68] See: https://www.edmonton.ca/transportation/RoadsTraffic/2017_SummerPark-RideReport.pdf

[69] Including the City of Edmonton, Leduc, Spruce Grove, Beaumont, Fort Saskatchewan, St. Albert, and Strathcona County. Data adapted from: http://www.transportation.alberta.ca/6093.htm

Green Transportation Technologies, Equipment & Innovation

The City of Edmonton's Sustainable Fleet Management Plan, developed in 2010, includes measures for driver education, hybrid vehicle purchases, vehicle right-sizing, increased use of biofuels, and trailer skirt installations which are expected to produce net reductions of 4,000 tonnes per a year by 2020.[70]

Pervasive internet access and recent technological developments have helped democratize portions of the market, giving rise to a "sharing economy". Car share businesses allow drivers to access vehicles for a rental fee without the expense of traditional car ownership. Residents who live within a car share service zone may choose to forego car ownership all together, resulting in fewer vehicles on the road. Pogo CarShare is an Edmonton-based company and is currently the only car share service in the City.

Edmonton's current transit fleet consists of 931 buses. Chinese automobile manufacturer BYD, the world's largest producer of electric vehicles, announced a partnership with Alberta in September 2016 to develop transit buses with zero-emission transportation technology. After testing battery powered electric buses, the City of Edmonton publicly announced that they plan on only purchasing electric buses beginning in 2020. Meanwhile, nearby St. Albert brought three long range, battery-powered electric buses into service in May 2017 and expects to bring four more online before 2018, which will represent 10% of its fleet.

Despite delayed deployment of electric buses, Edmonton introduced smart bus technology to all of its transit buses from 2011 to 2015. Smart bus technology improves convenience to bus transit riders by allowing them to track their bus's real-time location. In addition to improving the ridership experience, smart bus technology will help Edmonton Transit Services (ETS) improve reliability, predictability, and accessibility of its bus fleet.

Source: https://albertaventure.com/2015/03/copy-cars-pogo-car2go/

Pogo Carshare was launched in 2014 by local entrepreneurs after learning that Car2Go, the world's largest car sharing service, would not be expanding to the Edmonton market. Like Car2Go, members are able to pick up and drop off Pogo vehicles in a designated zone – Pogo's zone includes Edmonton's downtown core, Oliver, Old Strathcona, Riverdale and University areas. Rental fees are charged to a member's credit card at the end of each trip and includes gas, on-street parking, insurance, registration and maintenance. Members are either charged by the minute, hour or day. Pogo started with a fleet of 18 vehicles that has increased to 85, as of October 2017.

For passenger vehicles, the adoption of battery electric vehicles (BEVs) has been steadily increasing in Alberta over the past five years (see Table 6). Technological improvements and additional charging station infrastructure are believed to have encouraged the rapid growth in BEV purchases, despite a lack of regional incentives. An administration report to the City's executive committee predicted that there were approximately 235 BEVs and plug-in hybrid vehicles registered in Edmonton as of 2016, representing less than 0.1% of total passenger vehicle registrations in 2016.[71]

Table 6 - Conventional and BEV Purchases in Alberta

	2012	2013	2014	2015	2016
Total BEV Purchases in Alberta	14	38	42	104	159
Total Motor Vehicle Sales in Alberta	247,785	263,224	277,191	241,918	223,633
Total Passenger Car Sales in Alberta	59,383	62,568	59,892	51,845	47.733
Total Vehicle Registrations	4,569,980	4,764,093	4,952,037	5,098,281	5,110,089

Source: City of Edmonton and Statistics Canada

[70] See: https://www.edmonton.ca/city_government/documents/PDF/CityOperationsGHGManagementPlan.pdf

[71] See: https://www.cbc.ca/news/canada/edmonton/spend-300-000-on-charging-stations-for-electric-vehicles-edmonton-committee-says-1.3862880?cmp=rss

BEV infrastructure has also grown in Alberta and the Edmonton region. As of December 2017, there were approximately 41 public charging stations in the Edmonton region, representing roughly 20% of all charging stations in Alberta (see Table 7). A charging station pilot project was proposed by City Administration to Council called the "Plug 'n Go" program, which would install 70 stations on private properties throughout the City.[72] The project has yet to secure external funding, but the City Administration is scheduled to return to the Urban Planning Committee in early 2018 with an Electric Vehicle Strategy report.

Table 7 - Electric vehicle charging stations in Alberta.

EV Charging Stations in Alberta	Level 2	Level 3	Total
Greater Edmonton (within 50km)	32	9	41
Greater Calgary (within 50km)	58	8	66
Rest of Alberta	57	16	73
Total	**147**	**33**	**180**

Source: Canadian Automobile Association

Transportation Research & Development

Conceived in 2007, the Alberta Centre for Advanced Micro Nanotechnology Products (ACAMP) is an industry-led technology development centre that helps companies bring cutting-edge products to market. It is the only advanced product development centre in Canada to provide support to companies with technology at all stages of development. ACAMP created the Advanced Systems for Transportation (AST) in 2017, a consortium of 34 local and multinational companies focused on developing autonomous systems, including autonomous vehicles. Consortium members include automotive specialists, OEM representatives, federal, provincial and municipal governments, academia and innovative Alberta technology companies.[73] Since forming the AST consortium, there have been reports of autonomous vehicle testing on private land at Edmonton's International Airport and Research Park.

Research efforts focused on electric vehicles (EVs) within Alberta have garnered approximately $1 million in NSERC funding since 2012, with 73% of that funding reserved to post-secondary institutions in Northern Alberta – predominately at the University of Alberta (UofA).

The UofA's Eco-Car team has been competing in races around the world since 2012 with three net zero-emission vehicles that are propelled by hydrogen fuel cells.

In addition, the UofA's Centre for Smart Transportation (CST) began operating in 2012 with three faculty members who produce leading-edge transportation research related to traffic operations, planning, and safety. The CST has given rise to ACTIVE-AURORA, Canada's first Connected Vehicle (CV) test bed, which is expected to help Canada modernize its transportation sector through Intelligent Transportation Systems.

In 2017, NAIT, SAIT, and the BYD Company signed a letter of intent to create a certified training course for heavy-duty electric vehicles (HDEV). The program, with an anticipated start date of 2018, will be instructed by NAIT and SAIT teachers and is intended to train students to become HDEV technicians.

The Canadian Automated Vehicles Centre of Excellence (CAVCOE), based in Edmonton, advises organizations on how autonomous vehicles will impact their operations and business, assist with policy development, and also collaborate on research to gain a better understanding of autonomous vehicles and the opportunities that will arise over time.

[72] See: http://sirepub.edmonton.ca/sirepub/cache/2/jskcbsjnobqvpa5uzwcivdj0/59031912182017073044 4.PDF

[73] See: http://www.prweb.com/releases/2018/01/prweb15063034.htm

The ACTIVE-AURORA project is a three-year imitative launched in 2014 that consists of two test-beds and two laboratory test environments. Research is divided between Edmonton and Vancouver which are home to the ACTIVE and AURORA component, respectively. Project partners include three levels of government – Transport Canada, Alberta Transportation, the City of Edmonton – the University of Alberta's (UofA) Centre for Smart Transportation, the University of British Columbia (UBC), and industry partners.

Three on-road Alberta Co-operative Transportation Infrastructure and Vehicular Environment (ACTIVE) test-beds are located on congested corridors in Edmonton including a rural freeway (Anthony Henday Drive), an urban expressway (Whitemud Drive), and an urban arterial (23 Avenue). Researchers will evaluate how connected vehicle technology can be applied to:

- Transportation safety
- Traffic demand management
- Increase peak capacity and smooth traffic flow on busy roads.

The project is Canada's first connected vehicle test bed. It has received $1.3 million from the Asia-Pacific Gateway and Corridor Transportation Infrastructure fund and $2.36 million collectively from the Government of Alberta, the City of Edmonton, the UofA, the UBC, Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canada Foundation for Innovation.

See: https://www.alberta.ca/release.cfm?xID=4342706B2F973-F636-E821-D94C9596D4DB4460

4. Edmonton's Green Energy Economy Value Chain Gaps

Edmonton has many established strengths in the four sub-sectors studied but there remain areas that require further enhancement within the primary green energy sector value chain. Gaps identified for Edmonton's green energy economy include:

1. Facilities or sites for piloting / demonstrating new and emerging technologies.
2. Commercial manufacturing at a large-scale of technologies and components related to the green economy subsectors: renewable energy, energy storage, buildings, and transportation sectors.
3. Investment and financing firms with experience funding green energy sector projects.
4. System integrators and project developers with specialized experience in the energy storage sub-sector.
5. Global distribution networks for growing the export potential of Edmonton companies focused on the green energy sector.
6. Construction trades and builders (primarily residential) experienced in working with energy efficient products / technologies and processes.
7. Building operations staff experienced with high-performance buildings and related technology.
    - Note: This is a fundamental issue across Canada due to the current lack of relevant education and training programs for modern day buildings that are seeing an increasing high technology / ICT component.

Although a limited number of pilot and demonstration sites exist for emerging technologies in the Edmonton area (such as the Advanced Energy Research Facility), more are needed to enable technologies to transition from lab bench to commercialized products. Interconnected with the need for additional pilot and demonstration facilities is a need for funding and personnel experienced in financing green energy economy sector projects.

Opportunities exist for more niche equipment, technology, and component manufacturing across all sub-sectors. With respect to large-scale manufacturing, issues include Alberta's relatively high minimum wage, rising corporate tax rates, limited domestic market, and relatively isolated geographic location next to major global trade corridors.

As regulations are defined and technology continues to improve, energy storage project developers are expected to increase in number and experience. This value chain gap can be addressed relatively quickly in the coming years.

Building and construction related to the green energy economy represents one of the biggest opportunity areas out of the four sub-sectors studied. It is expected that the gaps in the value chain related to construction and buildings can be addressed relatively quickly in the near term as industry, trades, and building operators gain further experience with green building materials, technologies, processes, and operations.

5. Edmonton's Green Energy Economy Opportunities

With a changing local and global economy and an increased focus on sustainability locally, nationally, and internationally, opportunities are emerging that the City of Edmonton and local businesses can capture. Opportunities for Edmonton in the green energy economy are summarized by sub-sector below.

Renewable Power Supply & Alternative Energy

1. ***Renewable energy project design & planning***
   - Large, community, and small scale solar PV projects
   - Construction of wind energy assets
   - Geothermal opportunities at orphan well sites and leveraging oil & gas expertise for geothermal development
   - Geoexchange for heating applications
   - Applications related to geomatics, mapping, and GIS

2. ***Digitization & automation technologies***
   - Heavy emphasis on ICT, mechatronics, controls / sensors, software
   - Remote sensing of renewable energy resources and monitoring / optimization of assets
   - Big data / predictive analytics

3. ***Niche manufacturing across the renewable energy value chain***
   - Wind turbine towers and turbine components
   - Utilizing advanced manufacturing and 3D printing methods to increase local production of renewable energy system ancillary components
   - Solar racking
   - Balancing systems (inverters, combiner boxes, collection systems)
   - Controls and energy management systems

4. ***Bioenergy / biofuels / biogas capture & utilization***
   - Focusing on the waste-to-energy, anaerobic digestion, biofuels from agriculture, forestry, construction wastes, landfill biogas capture to be used for alternative fuels and/or electricity generation.
   - Closing loops on organic waste streams
   - Chemical byproducts of biofuel/biogas synthesis
   - Leverage local expertise to other jurisdictions

Energy Storage & Grid Infrastructure

1. ***Energy storage technologies***
   - Key technology areas include: lithium-ion batteries; compressed air energy storage (CAES); and flow batteries
   - Real time pricing in Alberta provides technical opportunities for energy storage (i.e., the stacking of services and price arbitrage)

2. ***Micro-grid systems & urban energy storage solutions***
   - Alongside solar PV / thermal, district energy (where relevant)
   - Increase resiliency to natural disasters
   - Mitigate price volatilities and transmission infrastructure challenges, which may allow for locational pricing
   - Community micro-grid in neighbourhoods

3. ***Smart grid technologies***
   - Demand response / energy management systems (community and building level)
   - Reactive power control systems
   - Development of new technologies to manage the electrical grid (e.g. security, privacy)
   - Software solutions to support energy storage and renewable energy integration
   - Net metering and virtual metering

4. ***Cloud-connected & data analytics services***
   - Power management apps
   - Cleanweb services (e.g., energy storage as a service)
   - Big data / predictive analytics

Green Building & Energy Efficiency

1. ***Net zero energy communities***
   - Consider integration of renewable energy, onsite co-generation, and storage systems

2. ***Smart / connected building technologies***
   - Examples (non-residential): Demand response, building energy monitoring, management, optimization, and automation systems, and other ICT-based solutions (reactive controls, sensors, software)
   - Examples (residential): Demand-side management (DSM) technologies

3. ***Cloud-connected & data analytics services***
   - Examples: Power management apps, 'cleanweb' services (e.g., lighting as a service), and big data / predictive analytics

4. ***Building design & project delivery software solutions***
   - Examples: BIM, 3-D design / visualization, and integration software

5. ***Energy efficiency retrofits & related professional services***
   - Existing buildings need to consider all the changes over time and be flexible with re-design and repurposing
   - Retrofits are a large job generator for the trades (i.e., 30:1 ratio of contractors to engineers on commercial retrofits)
   - Energy auditors / evaluators, energy modelers, and related service providers for buildings

6. ***Energy efficient prefabrication & modular construction***
   - Incorporating artificial intelligence (AI) and robotics into modular construction processes
   - Aligning with retrofit opportunity

7. ***Green building materials***
   - Examples: Engineered wood, recycled content materials, intelligent reinforced concrete, insulated concrete forms, and carbon-capture and utilization into value-added products like cement
   - Cold climate product manufacturing and testing

Green Transportation

1. ***Vehicle electrification***
   - Fleets, buses, and trucking industry (e.g., garbage trucks, delivery trucks)
   - EV charging infrastructure – in-line with potential building retrofits
   - Local niche manufacturing of electric vehicle charges, transformers, etc.
   - Fuel-cells for transport applications (e.g., for oil and gas, mining, and agriculture industries)

2. ***Autonomous vehicles & Artificial Intelligence (AI)***
   - Autonomous vehicles and driverless transportation systems for both commercial and industrial applications
   - Cold weather testing

3. ***Goods movement & logistics***
   - Opportunity for piloting new technologies (e.g., autonomous vehicles, electrification of long-haul trucking sector, etc.)

4. ***Smart transportation technologies***
   - Traffic and parking management solutions
   - Real-time traffic monitoring and pricing
   - Big data / predictive analytics

6. Recommendations for Accelerating Growth

The following tables provide a possible strategic framework with a number of supporting actions and considerations designed to help the City of Edmonton accelerate growth of the green energy economy sectors.

1. **Supporting Early-Stage Companies & Green Energy Economy Sector R&D**	
Support business mentorship and incubators	• Develop incentives that reduce costs for entrepreneurs and SMEs active in the green energy economy by providing shared services (e.g., shared professional services, real estate space such as offices, labs, meeting rooms, access to accelerators/ incubators, and mentoring groups, etc.). • Consider developing a City-led fund for supporting the incubation of green energy sector technologies and start-up companies. • Leverage partnerships and existing programs where possible with a green energy economy initiative focus (e.g., the Advanced Energy Research Facility)
Establish academic and research partnerships	• Develop stronger, more active partnerships with academia, private sector, industry associations, other levels of government in the green energy sector to reduce fragmentation of the ecosystem and develop stronger support for innovators and SMEs. • Work closely with existing academic institutions, including the University of Alberta and NAIT, to address local challenges and explore opportunities for research and collaboration on green energy sector technologies, systems, and applications (e.g., capstone projects, co-ops, research projects, etc.). • Undertake market research with industry associations, project developers, and other stakeholders to get current knowledge on the economic, technical, and environmental performance of renewable energy technologies in the local context. • Host incoming delegations and/or reverse trade missions (e.g., organized tours for incoming delegations in collaboration with Global Affairs Canada and AB EDT) to better understand Edmonton's strengths and build strategic partnerships around R&D. • Explore more opportunities for collaboration across the R&D value chain with other leading global R&D institutions and private sector companies (e.g., BYD, IBM, Siemens, etc.) active in targeted green energy segments such as energy storage and/or autonomous vehicle transportation.
Foster cluster development	• Explore co-location models for like-minded organizations and company clustering. • Develop industrial parks to focus on green energy economy sub-sectors–bring in support resources to attract green energy economy companies in that area. This could be in line with NAIT's interest in developing a technology 'demonstration' park. • Clustering efforts could include targeted partnership development and investment attraction efforts on a select number of 'anchor companies' to a given geographic location or zone (i.e., cleantech or eco-industrial park), with the supportive zoning, bylaws, and/or incentives to build out the ecosystem of suppliers and other supporting companies across the value chain to fill gaps. ○ Examples: Edmonton's waste management center with like-minded organizations undertaking research and commercial operations, as well as Greater Toronto Pearson eco-industrial park. • Consider value chain gaps and opportunities and push for components that could be made in Alberta (e.g., wind turbine towers), as well as through targeted investment attraction.
Support testing / demonstration of green energy sector technologies	• Explore public-private partnerships that look at showcasing local solutions, model their feasibility (e.g., using the Advanced Energy Research Facility), and test them in the real world to allow key stakeholders opportunities to learn from them. • Develop open-sourced demonstration sites, zones, or platforms and testing opportunities through targeted pilots that support local technology development and learning opportunities. • Explore pilots in areas such as renewable energy grid integration, smart grid management, intelligent transportation / logistics networks, and smart city initiatives. • Tie in with existing funding programs (e.g., ERA, Alberta Innovates, SDTC).

2. **Supporting Commercialization & Market Adoption of Green Energy Technology Solutions**	
City as a 'first adopter'	• Work with EPCOR and City Departments (e.g., Engineering) to explore more green energy technology deployment in areas that include smart transportation, smart / connected high-performance buildings, distributed generation, smart grid, energy storage, and/or micro-grid technology. • Remove barriers and provide support to green energy economy demonstration projects (e.g., micro-grid, autonomous vehicles, etc.), including consideration for a designated demonstration / pilot sites in parts of the city (e.g. northeast Edmonton, specific industrial lands). • Inventory the City's assets and institutions and identify opportunity areas where the City can mobilize them for green energy economy growth through public procurement (e.g., fleet vehicles, solar PV installations, incorporating green building materials, etc.). • Address procurement issues and challenges with respect to risk tolerance and ways to more actively embrace local technology solutions. • Create specific City-focused challenges (in areas such as smart buildings, micro-generation, biofuels for fleets, etc.) and/or explore programs such as Montreal's InnoCité or San Francisco's STIR that invite solution providers to address municipal challenges through an accelerated procurement process with an acceptable risk tolerance. ○ Example: Fund a local Hack-A-Thon to award cash to the most innovative new applications that reduce energy use for the City. • Consider implementing a municipal version of the Build in Canada Innovation Program that supports Canadian start-ups by buying the first products, and acts as the technology performance verifier. • Communicate a clear plan for cleantech deployment and/or a Roadmap for the City. • Develop a pilot investment fund available to local Edmonton companies – potentially leverage city assets as part of piloting process.
Encourage industry adoption and grow consumer demand	• Explore with industry the potential for developing 'challenge' programs and/or competitions that focus on green energy sector solutions (e.g., 'Race-to-Reduce', Hackathons, X-Prizes, etc.) • Develop 'innovation bootcamps' for SMEs and other private sector companies on technology adoption and integration and ways to improve operational competitiveness through green energy sector technologies. • Look at ways to lower risk for industry adoption, working with other government agencies to support loan guarantees, municipal voucher (similar to Advanced Education and Alberta Innovates' Innovation Voucher Program) to SME's to cover costs that will assist in overcoming first deployment financial barriers. etc. • Develop programs and incentives focused on increasing consumer demand for green energy / energy efficiency products and services (e.g., rebates for solar PV, EV charging infrastructure, or residential battery storage).
Support consortium building	• Support local companies in developing consortiums with other Canadian and international firms (e.g., EPCs) in order to be more competitive on a local and global level. • Work with other industry associations (e.g., APEGA, ACTIA, CanWEA, CanSIA, etc.) to encourage strategic partnerships and consortium building. • Consortium building could be done by establishing a firm understanding of Edmonton strengths / capabilities and needs / gaps, and then using a more coordinated match-making or partnership development approach with other government agencies (municipal, provincial, federal) and industry associations to fill local gaps and build more comprehensive / turnkey solutions (including technology and financing options) that could be exported domestically and/or globally (i.e.,, assembling expertise from other Canadian clusters to support Edmonton's strengths as a complete package).

Support policy changes and regulatory efforts	• Explore ways to remove regulatory 'red-tape' and fast-tracking / streamline the permitting process for innovative, green energy sector companies and their solutions (e.g., permits on green projects are accelerated, fees are reduced, etc.). • Drive industry demand for green energy sector products and services by developing leading policy and regulations and enforce such policy (e.g., building benchmarking, energy assessments / home energy labeling, etc.).

3. **Growing Awareness, Education & Collaboration Across the Ecosystem**	
Leverage existing businesses in the green economy sector	• Engage with local businesses that have succeeded in this space and understand what has made them successful but also what their needs are to keep growing. • Collaborate with local businesses (particularly those with offices outside of Alberta) to promote Edmonton's strengths outside the Edmonton region. • The City of Edmonton could work to support local companies with their domestic and international marketing efforts (including their presence at events, with the provision of marketing materials, and with developing joint promotional materials and marketing / media campaigns). • Support cross sub-sector collaboration (e.g. solar PV with buildings, etc.). • Host, participate in, and support industry events, competitions, and awards related to the green energy sector and growing the supplier / value chain.
Increase public awareness and engagement	• Promote Edmonton's green energy economy opportunities through targeted marketing and promotional campaigns. • Work with others (e.g., industry associations, Chamber of Commerce) to market and promote local expertise, products, and services to domestic and international community through website platform, directories, newsletters, and other tools. • Improve energy literacy by working with EPCOR and other key stakeholders on targeted education and promotional campaigns. • Support building energy labelling efforts (voluntary with goal of moving to mandatory). • Host "open door" events on various green economy topics to bring the public and stakeholders together. • Report out on successes of demonstration programs and provide data so that others can learn from these successes. • Develop case studies on successful local green energy economy companies and projects (e.g., green buildings) and their benefits to Edmonton. • Work with local media to promote success stories (e.g., one segment a week on a local evening newscast), how the green energy economy can work with conventional energy sector, what jobs are transferrable, the business and investment opportunities, local capabilities, etc. • Communicate the potential cascade effect of various technologies (e.g., AI) in the local community and how those will benefit Edmontonians
Grow industry education and training	• Grow more "high performance" green building expertise (e.g., energy advisors and trades) through on the job training, institutional, and apprenticeship programs. • Support professional development and retraining efforts and programs to help transition workers into Alberta's green energy sector. • Work with NAIT and others to address curriculum changes needed to allow for new processes, skills, and technologies to be integrated into the trades and courses/ • Target youth to move to 'more affordable' Edmonton from other Canadian cities (e.g., Toronto, Vancouver) to work in green energy economy. • Consider expanding cooperative education opportunities for youth engagement on green energy sector projects, including working on City of Edmonton projects.

Support cross-government and industry collaboration and coordination	• Advocate for improved policy that supports the green energy sector companies and levels the playing field. Example: ○ Work with the AESO, the Province of Alberta, EPCOR, and others to streamline and improve policies for energy storage projects, removing regulatory barriers / inhibitors, and 'red tape'. • Provide a 'concierge service' for green energy sector SMEs that includes information sharing for companies in collaboration supported by other levels of government and organizations such as NRC, AI, etc. • Consider hosting a regular 'information sharing' meeting or roundtable every 2-3 months with other levels of government in Alberta or the Edmonton region. • Consider collaborative efforts with other major cities in the province (e.g. Red Deer, Calgary). • Develop a roundtable/think tank/committee of green economy SMEs to provide ongoing recommendations/input to the City on the sector.
Work with financial sector to improve access to capital	• Develop a process to bring together "traditional" investors with green investors to improve understanding of green energy sector investment. • Increase financial institution support by reducing risk through education / information. • Engage with financial institutions to focus on removing barriers to supporting innovation and providing suitable financial products that support green energy economy sector growth. • Explore Property Assessed Clean Energy (PACE) financing and other financing models (e.g., Multi-Asset Renewal Fund, solar funds, solar share co-ops, green investment bank, green bonds, etc.) as possible options for advancing green energy sector projects and initiatives.

7. Conclusions

As renewable energy and other clean technologies become increasing affordable, the demand from consumers grows, and public policy drivers further accelerate market adoption, the pace for transition to a green energy economy will continue to accelerate. The City of Edmonton is well positioned in many respects to capitalize on this transition.

As an energy hub in North America with available talent, Edmonton's green energy economy value chain is already well-developed, with nearly 15,000 jobs and contributing $1.79 billion to provincial GDP in 2016. Significant strengths lie in Edmonton's expertise related to green building design and construction, as well as solar PV system development, automation / sensors, and smart transportation solutions.

In order to continue growth and diversification of its green energy economy, the City of Edmonton may wish to strategically target efforts around three themes:

4. Ways to support early-stage companies and SMEs with business development and growth focused on exports markets and tapping into the growing global demand within key sectors.
5. Ways to drive the demand for more localized, community-scale green energy economy projects within their own jurisdiction in the areas of green building and energy efficiency, smart transportation, renewable energy, micro-grids and energy storage, and smart city solutions.
6. Growing awareness for the opportunities, supporting education, and promoting collaboration across the green energy economy ecosystem with Edmonton residents and businesses.

Showcasing Edmonton's green energy economy story to both local residents and to the world is an important piece. Where to focus in terms of the specific segments, technologies, and service areas, as well as key partnerships (domestic and international) will be important for success and must consider both existing strengths as well as the future direction of the industry and global market trends.

Edmonton must establish a unique strategic position that enables it to differentiate from other Canadian and global cities that are also looking to grow their green energy economies, and will need to market and promote itself accordingly. There is also a need to work with important local stakeholders to build buy-in and demonstrate the economic imperative that exists around the green energy economy transition.

Appendix A: Project Methodology

This Appendix summarizes the methodology for all secondary and primary research activities carried out by The Delphi Group in 2018 as part of the Edmonton Region's Green Energy Economy study. This work involved:

1. **Developing a 'green energy economy' statistical framework** to support sub-sector profiling**;**
2. **Undertaking secondary research to profile the four green energy sub-sectors** in terms of key projects, companies, investments, and research activities;
3. **Developing estimates of employment and GDP** within the four green energy sub-sectors under investigation;
4. **Developing a green energy company database**;
5. **Undertaking SWOT, value chain mapping, and gap analyses**;
6. **Conducting in-depth interviews with industry leaders** involved in Edmonton's green energy economy; and
7. **Organizing a green energy economy focus group** focused on Edmonton's potential opportunities and positioning in line with its current strengths and value chain gaps.

The research methodologies used to address each of the points listed above are discussed in detail in the following sub-sections.

1. Developing the 'green energy' economy statistical framework

Delphi began by establishing a clear and common definition and overarching framework for Edmonton's green energy economy. For the purposes of this research, the project team focused on the following four (4) sub-sectors[74]:

- **Renewable power supply & alternative energy** – including wind, solar, geothermal, hydro, biomass, waste heat to power.
- **Energy storage & grid infrastructure** – including batteries, battery management systems, smart meters, fuel cells, energy management software, and other smart grid applications.
- **Green buildings & energy efficiency** – including products, services, and materials related to energy efficient building design, construction, renovation, and operations such as HVAC, windows, lighting, and control systems.
- **Green transportation** – including electric vehicles, e-bikes, public transit, rail, as well as related technologies and infrastructure.

Delphi finalized a list of statistical codes using NAICS[75] that encompass the proposed green energy economy definition and relevant sub-sectors above. There has already been extensive work undertaken in this space by the Delphi Group and others, which served as the foundation and cross-reference for this study. Delphi used the best available sources and standards for this effort.

2. Undertaking secondary research to profile the four green energy sub-sectors

Delphi undertook secondary research, reviewing existing reports, websites, articles, and other available information on the various green energy sub-sectors, including information on key companies, research initiatives, demonstration / pilot projects, investment activities, important stakeholder groups, policy and program drivers, and other details to map out current activities and cluster strengths.

Delphi also tabulated the number of establishments by employment size group for each of the relevant green energy industry NAICS codes from the Statistics Canada Business Patterns database for the City of Edmonton and surrounding region.

In addition to the Industry Canada Company Capabilities, InfoCanada, and Hoover's databases, Delphi analyzed:

[74] Please Note: The relevant value chain manufacturing will be considered as part of the analysis on all of the four green economy sub-sectors and included in those individual sub-sector profiles.

[75] NAICS = North American Industry Classification System

- Information from key trade or industry association organizations, such as databases of member or known companies;
- National, regional, and city-level research studies on the core green economy sector or relevant sub-sectors.

3. Developing estimates of employment and GDP

The Delphi Group used a bottom up approach in order to develop estimates of employment and GDP, utilizing data published by Statistics Canada, which was then validated and verified through a range of other sources (including InfoCanada and Hoover's company data, industry association membership lists, indicator data from green certification programs, NSERC and ERA funding, and key informant interviews) to estimate the amount of activity within relevant key industries. Below is a more fulsome overview of the methodology that was applied:

1. Total jobs for the industries (4-digit NAICS) identified for the four green energy sub-sectors were prepared based on both labour force and employment data from the Statistics Canada National Household Survey (NHS) for Edmonton Census Metropolitan Area and job estimates derived from the Statistics Canada Business Patterns database.
2. The jobs based on both sources were compared and through similar results it was concluded that the Canada Business Patterns was a legitimate source by which to estimate detailed employment at the 4-digit NAICS level for the Edmonton Region.
3. The next step was to estimate 'green' intensity ratios for each industry (4-digit NAICS) in the four groups. Intensity ratios are essentially the amount of 'green energy' sub-sector activity happening within a given industry, expressed as a % or number from 0 to 1.00.
4. The intensity ratios were derived through examining Alberta's and Edmonton's related 'market penetration' of activities related to the green energy economy in each of the relevant industries at the 4-digit and 6-digit NAICS code level.
5. Key indicators that were used to estimate market penetration include, as examples, the amount of renewable electricity as a percentage of total generation, the amount of new renewable energy capacity built over the last year as a % of total capacity added, the number of buildings and homes certified under a recognized third-party program as a percentage of total new construction, and the amount of research grants flowing to green energy sector technologies areas as a percentage of total research grant funding. Third-party certification programs considered in the analysis included LEED (for both new construction and existing buildings), BOMA BESt (for existing buildings in AB), Built Green (for new home construction), and ENERGY STAR (for homes, and equipment / appliance manufacturing and repairs).
6. In some cases, where estimating market penetration was not possible due to limited data, we used intensity ratios developed by The Delphi Group on other studies and/or research from other sources such as the US DOE (for ENERGY STAR equipment and appliances) and US Bureau of Labor Statistics as the benchmark and adjusted based on our understanding of the AB market.
7. Relevant 'green energy' jobs were then estimated by applying these intensity ratios to each of the total jobs that had been derived from the Canada Business Patterns for the Edmonton Region at the 4-digit NAICS code level and validated through job counts from the Statistics Canada National Household Survey.
8. Green jobs were subsequently converted to green energy economy output and GDP through multipliers for Alberta that were provided to the project team by the Statistics Canada National Accounts (Input Output) Division.

The method applied in this study mirrors the approach taken by the Delphi Group as part of a similar study for Calgary Economic Development in 2016, as well as approaches that have been developed and applied in other jurisdictions by organizations such as the Vancouver Economic Commission (VEC)[76] for the City of Vancouver and the US Bureau of Labor Statistics (US BLS)[77] in their green job estimates.

However, one fundamental difference with this study as opposed to the VEC and US BLS work referenced above is that no industry survey to companies in each of the relevant industries (at the 6-digit NAICS code level) was performed in order to further refine intensity ratios. Instead, the work has relied on available data, market penetration estimates, and qualitative information from

[76] Vancouver's Green Jobs estimate and 2014 update: http://www.vancouvereconomic.com/wp-content/uploads/2015/04/VEC_GreenJobsReport_2014_web.pdf
[77] See US BLS's Green Goods and Services 2010-2012 study: http://www.bls.gov/ggs/home.htm and http://www.bls.gov/news.release/pdf/ggqcew.pdf

stakeholder interviews to refine the intensity ratios as best as possible. Future updates to job and GDP estimates following this methodology could consider including an industry survey for further accuracy.

The final employment and GDP estimates by sub-sector, including intensity ratios, can be found in the tables at the end of Appendix A.

4. Developing a green energy company database

Delphi worked with both publicly and privately available business directories and databases to compile a list of relevant companies by green economy sub-sector. Companies were identified through secondary business data, trade / membership body databases, and the research team's knowledge of key businesses and networks in Alberta. Directories included:

- GLOBE Series Conference and Expo database;
- Industry Canada Company Capabilities database;
- Hoover's database;
- Relevant sector-specific reports;
- Various industry association membership lists; and
- Various corporate directories including Scotts, Yellow Pages, and directories either published by or linked to by the Provincial Government.

5. Undertaking SWOT, value chain mapping, and gap analyses;

Delphi conducted an analysis of the strengths, weaknesses, opportunities, and threats (SWOT) associated with the green energy economy and related sub-sectors for Edmonton and surrounding area. The SWOT analysis was based on the extensive research carried out for this project and validated through strategic and targeted industry outreach as described below.

Delphi highlighted key observations as it relates to the green energy economy sub-sectors in Edmonton and surrounding area, including how current federal and provincial priorities related to green economy and climate change policy and investments, as well as global megatrends, may impact on existing or potential future business and investment attraction opportunities, create inherent risks, and/or generate export development possibilities for local businesses. The SWOT also highlights how Edmonton and other key stakeholders in Alberta may consider positioning in order to capitalize on the opportunities and mitigate potential threats by addressing existing weaknesses.

In addition to the SWOT analysis, value chain mapping was conducted based on examining input-output related sources and by examining Alberta based international trade for "green" commodity exports.

Delphi (and previously GLOBE Advisors) have developed a detailed list of green HS commodity codes by which Canada and other World Trade Organization (WTO) countries classify the movement of international trade. This list of green HS commodity codes was initially developed by the United States International Trade Administration (ITA) for environmental goods and services including renewable energy technologies. This list has been modified and new commodities added by Delphi over the past few years through several international trade related consulting assignments.

Green energy sector exports and imports were tabulated from this amended HS commodity code list for Alberta. Subsequently, the total Alberta production for these commodities were estimated through export intensity multipliers that are included in the Input Output multipliers that Statistics Canada provided to us. Production data for these green commodities were converted to 4-digit NAICS codes and an Input Output shock was prepared in order to derive a value chain of the upstream industries associated with this green output.

The resultant set of green energy value chains for the four sub-sectors were then compared with highly relevant value chains developed for two other Input Output related work that the consultants had been working with. These included an Input Output shock for electricity production that showed the detailed upstream industries that were involved; another on green buildings that showed the relevant upstream industries and another value chain derived for green transportation components from the Statistics Canada Input Output Accounts.

In addition to the development of Input Output derived value chains for the four green groups, the consultants worked with an economic impact model developed by the United States National Laboratory for Renewable Energy (NREL) that more specifically shows the upstream components for solar power, wind power, geothermal, run-of-river hydro, large hydro, cellulose ethanol and pyrolysis (bio-crude oil / syn gas). The NREL model provided more specific component industries for each of these renewable energy technologies.

A value chain gap analysis was then undertaken. The gap analysis was estimated by showing the number of business counts for each industry component of the value chains that were identified through both the Statistics Canada Input Output modeling and the upstream renewable energy technologies identified through the NREL model.

6. Conducting in-depth interviews with industry leaders

Delphi developed a prioritized list of industry leaders, experts, and key stakeholders for key informant interviews. The Delphi project team interviewed 20 key industry stakeholders in order to build on existing knowledge, fill-in research gaps, review the relevant industry and market trends, test potential investment attraction strategies, and validate the preliminary SWOT and value chain gap assessments.

Delphi interviewed a diverse number of players across the value-chain including:

- Relevant industry associations and non-profit organizations (e.g., CanWEA, CanGEA, etc.)
- Government bodies, research agencies, and post-secondary institutions (E.g., City of Edmonton, Edmonton Economic Development, Alberta Innovates, NAIT, etc.)
- Equipment and technology suppliers (firms of different sizes and from the relevant sub-sectors)
- Firms supplying green energy related services (architecture, design, consulting, etc.)
- Financial players (e.g., VC firms, etc.)

Delphi used an interview questionnaire and conducted the interviews both in person and by telephone, allowing for contact with respondents in geographically dispersed locations. Delphi then summarized the interviews and integrated the key findings into the study.

7. Organizing the Green Energy Economy focus group

Delphi organized a green energy economy focus group on February 1, 2018, hosted at the City of Edmonton. The focus group was designed to seek additional feedback and input from stakeholders on the research and key findings, including the investment attraction opportunities, key barriers and risks, and the initial SWOT and value chain gap analysis.

The Delphi project team ensured that focus group participants provided a cross-section of individuals representing businesses, R&D agencies, educational institutions and training bodies, government, and other key stakeholder groups.

Approximately 4 hours in length, the focus group session was attended by approximately 25 industry stakeholders and consisted of two 40-minute presentations that were followed immediately by focus group discussions at breakout tables facilitated by Delphi Group staff.

Intensity Ratio	Renewable Power Supply & Alternative Energy	Total Jobs	Green Jobs	Green Gross Output ($ Thousands)	Gross Output per Job ($ Thousands)	Green GDP ($ Thousands)
0.014	2211 - Electric power generation, transmission and distribution	4,880	70	$27,884	$399.58	$17,254
0.000	2379 - Other heavy and civil engineering construction	445	0	$16	$446.95	$6
0.006	2389 - Other specialty trade contractors	7,030	39	$10,281	$265.90	$4,199
0.000	3336 - Engine, turbine and power transmission equipment manufacturing	350	0	$0	$0.00	$0
0.250	3344 - Semiconductor and other electronic component manufacturing	255	64	$11,090	$173.97	$4,663
0.100	3353 - Electrical equipment manufacturing	480	48	$19,674	$409.87	$7,369
0.009	5413 - Architectural, engineering and related services	16,135	152	$40,085	$264.29	$23,912
0.000	5414 - Specialized design services	1,535	0	$0	$0.00	$0
0.004	5416 - Management, scientific and technical consulting services	7,030	28	$5,405	$192.21	$3,446
0.035	5417 - Scientific research and development services	1,415	50	$10,597	$213.97	$7,455
0.040	5622 - Waste treatment and disposal	760	30	$9,230	$303.63	$7,128
	Total	**40,315**	**480**	**$134,263**	**$279.74**	**$75,431**

Intensity Ratio	Energy Storage & Grid Infrastructure	Total Jobs	Green Jobs	Green Gross Output ($ Thousands)	Gross Output per Job ($ Thousands)	Green GDP ($ Thousands)
0.014	2211 - Electric power generation, transmission and distribution	4,880	70	$27,884	$399.58	$17,254
0.001	2371 - Utility system construction	8,305	8	$3,833	$461.50	$2,124
0.000	3336 - Engine, turbine and power transmission equipment manufacturing	350	0	$0	$0.00	$0
0.118	3345 - Navigational, measuring, medical and control instruments manufacturing	750	89	$15,396	$173.97	$6,474
0.100	3353 - Electrical equipment manufacturing	480	48	$19,674	$409.87	$7,369
0.050	3359 - Other electrical equipment and component manufacturing	155	8	$1,501	$193.65	$685
0.003	5413 - Architectural, engineering and related services	16,135	50	$13,219	$264.29	$7,886
0.000	5414 - Specialized design services	1,535	0	$0	$0.00	$0
0.002	5416 - Management, scientific and technical consulting services	7,030	12	$2,297	$192.21	$1,464
0.020	5417 - Scientific research and development services	1,415	28	$6,055	$213.97	$4,260
	Total	**41,035**	**313**	**$89,860**	**$287.45**	**$47,515**

Intensity Ratio	Green Building & Energy Efficiency	Total Jobs	Green Jobs	Green Gross Output ($ Thousands)	Gross Output per Job ($ Thousands)	Green GDP ($ Thousands)
0.051	2361 Residential building construction	13,790	703	$230,894	$328.31	$97,647
0.185	2362 Non-residential building construction	10,245	1,895	$729,323	$384.80	$283,791
0.098	2372 Land subdivision	715	70	$31,286	$446.95	$12,097
0.020	2379 Other heavy and civil engineering construction	445	9	$3,978	$446.95	$1,538
0.100	2381 Foundation, structure, and building exterior contractors	7,800	780	$348,622	$446.95	$134,800
0.100	2382 Building equipment contractors	21,220	2,122	$564,243	$265.90	$230,423
0.100	2383 Building finishing contractors	13,360	1,336	$355,244	$265.90	$145,073
0.100	2389 Other specialty trade contractors	7,030	703	$186,929	$265.90	$76,337
0.100	3141 Textile furnishings mills	55	6	$693	$125.91	$305
0.100	3149 Other textile product mills	190	19	$2,392	$125.91	$1,055
0.900	3219 Other wood product manufacturing	915	824	$237,176	$288.01	$90,942
0.098	3255 Paint, coating and adhesive manufacturing	135	13	$5,589	$422.90	$2,412
0.098	3273 Cement and concrete product manufacturing	1,495	146	$71,720	$490.02	$31,594
0.098	3274 Lime and gypsum product manufacturing	20	2	$640	$326.86	$270
0.098	3323 Architectural and structural manufacturing	3,420	335	$110,557	$330.20	$46,596
0.300	3334 Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	620	186	$39,009	$209.72	$19,472
0.165	3345 Navigational, measuring, medical and control instruments manufacturing	750	124	$21,529	$173.97	$9,053
0.810	3351 Electric lighting equipment manufacturing	70	57	$10,842	$191.22	$4,706
0.750	3352 Household appliance manufacturing	65	49	$9,449	$193.82	$2,796
0.350	3353 Electrical equipment manufacturing	480	168	$68,859	$409.87	$25,790
0.350	3359 Other electrical equipment and component manufacturing	155	54	$10,505	$193.65	$4,793
0.185	3372 Office furniture (including fixtures) manufacturing	130	24	$3,569	$148.38	$1,630
0.098	3379 Other furniture-related product manufacturing	115	11	$3,758	$333.78	$1,374
0.006	5413 Architectural, engineering and related services	16,135	97	$25,586	$264.29	$15,263
0.010	5414 Specialized design services	1,535	15	$1,167	$76.02	$634
0.010	5415 Computer systems design and related services	8,035	80	$14,914	$185.61	$9,554

Intensity Ratio	Green Building & Energy Efficiency	Total Jobs	Green Jobs	Green Gross Output ($ Thousands)	Gross Output per Job ($ Thousands)	Green GDP ($ Thousands)
0.024	5416 Management, scientific and technical consulting services	7,030	169	$32,430	$192.21	$20,674
0.015	5417 Scientific research and development services	1,415	21	$4,542	$213.97	$3,195
0.098	5617 Services to buildings and dwellings	13,850	1,356	$99,397	$73.31	$53,861
0.050	8112 Electronic and precision equipment repair and maintenance	695	35	$6,147	$176.90	$3,995
0.050	8113 Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance	4,315	216	$38,166	$176.90	$24,803
0.050	8114 Personal and household goods repair and maintenance	840	42	$2,527	$60.16	$1,697
	Total	**137,070**	**11,666**	**$3,271,679**	**$280.43**	**$1,358,169**

Intensity Ratio	Green Transportation	Total Jobs	Green Jobs	Green Gross Output ($ Thousands)	Gross Output per Job ($ Thousands)	Green GDP ($ Thousands)
0.000	3336 Engine, turbine and power transmission equipment manufacturing	350	0	$0	$0.00	$0
0.000	3353 Electrical equipment manufacturing	480	0	$0	$0.00	$0
0.000	3359 Other electrical equipment and component manufacturing	155	0	$0	$0.00	$0
0.000	3361 Motor vehicle manufacturing	280	0	$0	$0.00	$0
0.000	3363 Motor vehicle parts manufacturing	295	0	$0	$0.00	$0
1.000	3365 Railroad rolling stock manufacturing	15	15	$1,052	$70.11	$641
0.000	3369 Other transportation equipment manufacturing	65	0	$0	$0.00	$0
0.650	4821 Rail transportation	1,790	1,164	$348,160	$299.23	$211,048
0.850	4851 Urban transit systems	830	706	$44,848	$63.57	$65,306
0.100	4859 Other transit and ground passenger transportation	240	24	$2,843	$118.48	$1,883
0.650	4882 Support activities for rail transportation	255	166	$37,438	$225.87	$18,239
0.006	5416 Management, scientific and technical consulting services	7,030	42	$8,108	$192.21	$5,168
0.010	5417 Scientific research and development services	1,415	14	$2,937	$213.97	$2,066
0.001	8111 Automotive repair and maintenance	6,645	4	$481	$113.08	$283
0.090	8114 Personal and household goods repair and maintenance	840	76	$4,548	$60.16	$3,054
	Total	**19,674**	**2,210**	**$450,414**	**$203.85**	**$307,689**

Appendix B: SWOT Analysis

The list below is a summary of a strengths, weaknesses, opportunities, and threats (SWOT) analysis designed to help better understand the current state of the City of Edmonton and surrounding region's green energy economy and related sub-sectors. This list was created based on secondary research, feedback obtained from industry stakeholders during consultation, as well as a review of current federal and provincial policy and investment priorities.

STRENGTHS

- City of Edmonton has shown early leadership around its climate change strategy and energy transition plan.
- Sustainability is discussed holistically by considering many elements across different stakeholders (e.g., lighting affects customers, sky, electricity usage, etc.).
- ERA serves as an established funding vehicle for investing in green energy economy projects and solutions.
- The Edmonton region, and Alberta more generally, currently has an abundance of entrepreneurial 'knowledge' workers with experience in the energy sector (primarily oil and gas) with transferrable skill sets, including professional engineers, trades, and related services such as ICT specialists.
- Considerable experience exists in Alberta for developing a broad range of renewable energy projects (including utility-scale wind, solar, and hydro, as well as district energy, bioenergy, and commercial scale and residential solar PV projects), as well as transferrable expertise in geomatics, mapping, GIS, and sensors.
- Edmonton and surrounding region is a goods manufacturing hub for Alberta's oil and gas industry with large industrial parks. Heavy manufacturing may be transferrable to other sectors (e.g., green products for buildings, wind turbine towers, etc.).
- The University of Alberta and NAIT are key research and development hubs for smart grid, energy systems, prefabricated and modular building, autonomous systems (including vehicles), connected vehicles, machine learning and artificial intelligence, and nanotechnology materials development (e.g., Centre for Sensors and System Integration, Centre for Applied Technology, and the University of Alberta's Alberta Machine Intelligence Institute, Centre of Excellence for Smart Transportation).
- Education and training programs in clean energy and energy efficiency exist at local post-secondary institutions, including NAIT's Alternative Energy Technology program, trades training, computer science, chemistry, and engineering.
- Due to its location, Edmonton is a large manufacturing hub for northern municipalities interested in green building development.
- Edmonton has relatively strong expertise in energy efficient modular construction and pre-fabrication, as well as expertise in the design of net zero energy homes and communities.
- Many service providers in the industrial energy efficiency space exists in Alberta – a strength that could be transferred to other sectors / industries.
- Technology startups in the Edmonton region have expertise across the green economy including smart transportation, energy storage materials and devices, sensors, and artificial intelligence.
- Close collaboration between government and industry in biofuels development (e.g. the Edmonton Waste Management Centre, Advanced Research Energy Centre, and Enerkem's waste-to-biofuels plant).

WEAKNESSES

- Current low energy prices (based on natural gas and coal-fired electricity) combined with the lack of peak and time-of-use pricing makes it a challenge for renewable energy options to compete without the provincial Renewable Electricity Program
- The Edmonton region has a small / niche manufacturing base with many products, equipment, and technology imported from outside the province of Alberta.
- Alberta is a relatively small market from a global perspective making 'economies of scale' a challenge in terms of large-scale manufacturing of renewable energy equipment and technologies and green materials
- Alberta has relatively high labour costs compared to global manufacturing centres, making manufacturing a further challenge from a cost competitiveness perspective.
- Low profile of local green building products – construction industry sourcing products from outside Edmonton and Alberta.
- Research and development activities in the energy sector are still largely focused on oil and gas resulting in a nascent, small, green technology sector. Outside of O&G, Edmonton is focused on research and development within health care and agribusiness sectors.
- Low public awareness of the potential benefits of renewable energy and energy efficiency in Alberta and with respect to broader energy literacy, creating real and perceived barriers.
- Until 2017, Alberta was the only jurisdiction in Canada and the US without energy efficiency programs.[78] Low energy efficiency priorities have likely resulted in education gaps for local residents / public, investors, private sector, and City officials on the green energy economy opportunities.
- There is a lack of market demand or 'receptor' capacity for local technology – lots of research and interest in innovation but support is needed downstream with commercialization, procurement, and industry adoption.
- Slow action on rapidly emerging technologies may result in Edmonton falling behind to the point that it has difficulty catching up.
- Risk aversion related to fear of acting on new technologies as investing too early may result in technology development / adoption 'paralysis', discouraging innovation and investment.
- Current policy double charges energy storage companies (T&D) as both a producer and a consumer.
- A lack of job experience and expertise to retrofit Edmonton's existing building stock.
- Limited support for green fleets and autonomous vehicles in the form of policies, incentives, and public refueling / charging infrastructure.

OPPORTUNITIES

- Global megatrend toward the 'digitalization' and automation of the energy, building, and transportation sectors.
- Increasing global application of cloud-connected services, software development, and predictive data analytics to support energy, buildings, and transportation system optimization and efficiencies (e.g., wind monitoring centres).
- Increasing application of geomatics, GIS, and sensors-based expertise to renewable energy sub-sector, including remote sensing and real-time monitoring, asset optimization, etc.
- Under-employed oil and gas workers and a large number of abandoned wells may present opportunities to develop geothermal energy.
- Growing concerns over waste management coupled with an increasing appetite for renewable energy encourages waste-to-energy projects (e.g., biogas capture for energy production, anaerobic digestion for fueling municipal fleets, etc.)
- Large seasonal weather extremes (between -30°C to +30°C) make Edmonton a unique test-bed for different green products such as green building products, renewable energies, distributed generation, micro-grid, energy storage solutions, EVs, connected and autonomous vehicles.
- An aging building stock (30-35 year range) presents large retrofit potential.
- Improving energy efficiency education gaps presents an opportunity for rapid / low cost energy efficiency gains within the Edmonton region.

[78] See: http://www.pembina.org/reports/kick-starting-ee-alberta.pdf

- Edmonton's large temperature ranges are useful for understanding how energy efficient buildings, autonomous and electric vehicles work in different climates.
- Anticipated rapid growth of electric and autonomous vehicles for commercial and personal uses (e.g., the global autonomous vehicle market is expected to be valued at $126.8 billion by 2027).[79]
- A change in urban form preferences towards denser, mixed-use developments, with access to public transportation.
- Increasing usage of integrated robotics, ICT, automation systems, and AI into the construction industry.
- Emerging supportive policy landscape (both federally and provincially), including renewable energy targets, the retirement of coal-fired electricity, and a broad-based price on carbon.
- Available funding at the federal and provincial level for innovation spending (e.g. Emissions Reduction Alberta (ERA), Alberta Innovates and Sustainable Development Technology Canada (SDTC)).
- Available funding at the federal and provincial level for green / public transport infrastructure under Public Transit Infrastructure Funding (PTIF) and the Alberta Government's Green Transit Incentives Program (GreenTRIP).
- Increased energy efficiency funding from the Climate Leadership Plan's carbon levy through Energy Efficiency Alberta. Higher certainty of this funding remaining in place over the medium-term is provided by the federal government's carbon pricing backstop under the Pan-Canadian Framework. The carbon pricing backstop also mitigates competitiveness pressure from other provinces which had not intended on enforcing carbon pricing.
- Low energy prices combined and favourable U.S. currency exchange rate at present can serve to attract manufacturing to Alberta.

THREATS

- Integration of renewables could impact on grid reliability without effective smart grid and energy storage infrastructure in place.
- Future changes to provincial or federal government could change the policy landscape in Alberta, removing some of the policy / program drivers, investments and/or incentives for developing more green energy economy projects.
- Push-back from the public and/or lack of public support for renewable energy projects may create challenges with 'NIMBYism'.
- Fears that investment capital tied up in conventional energy sector could be stranded in the province because of policy changes resulting in push-back from certain sectors.
- The rapid evolution of technology and/or breakthrough products or processes could render current investments in today's technology and infrastructure obsolete and/or costlier in the long-run.
- Climate change impacts may affect certain technologies more than others (e.g., changes to hydrological cycles could impact on the availability of water for hydroelectricity generation).
- Uncertainty about trade agreements and lower corporate tax rates from the United States erode Canada's tax advantage, making Edmonton a less attractive investment destination.
- Changing transportation landscape may arrive quicker than expected requiring municipality to respond rapidly when demand arrives with policy and infrastructure investments.
- Brain drain, or the loss of those educated in green economy to other jurisdictions where green economy jobs and companies are more prominent.

[79] See: https://www.businesswire.com/news/home/20170711005684/en/126.8-Billion-Autonomous-Vehicle-Market-2017-2023--