

TECHNOLOGY ROADMAP

Investing in technologies
for a lower carbon future.

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Overview of ERA's Technology Roadmap

PURPOSE

Emissions Reduction Alberta (ERA)¹ has a mandate to identify and accelerate innovative solutions that reduce greenhouse gas (GHG) emissions and secure Alberta's success in a lower carbon economy. ERA invests in transformative technologies and convenes complete solutions that will help the province build a sustainable and diversified economy that attracts investment, delivers improved environmental outcomes, and creates new employment opportunities. The goal of this Technology Roadmap (TRM) is to articulate the pathways for Alberta to become a global hub for innovation and technology for a low carbon world.

ERA worked with government, industry, and innovators to develop the TRM, which guides ERA's investment decisions and informs its portfolio mix. The TRM is also intended to contribute to alignment of the broader innovation system around common climate leadership and innovation goals that result in meaningful GHG reductions in Alberta.

KEY PRINCIPLES AND INSIGHTS

The TRM builds from five key investment principles or insights that are central to its success:

- 1 Leverage Alberta's Unique Strengths** - ERA's investment strategy will position Alberta to play a unique role in, and make a unique contribution to, a low carbon emissions' future, particularly with respect to leveraging its vast hydrocarbon resources.
- 2 Think from the Future** - ERA will prioritize its investments based on the most effective pathways toward achieving a low carbon future. This may or may not always align with priorities that emerge based on Alberta's current emissions profile.
- 3 Pursue Complete Solutions** - A focus on technology alone is not enough given the multitude of other factors that can either inhibit or enable a technology's success.
- 4 Avoid Silos** - Greater benefits will be realized through an investment strategy that considers partnerships and combines focus areas and technologies to form integrated solutions.
- 5 Lead the System** - ERA is uniquely positioned in Alberta's energy, climate, and innovation ecosystem to play a leadership role in taking the "long-view" for the public interest, and to help the system identify strategic pathways for private and public investment in climate and innovation.

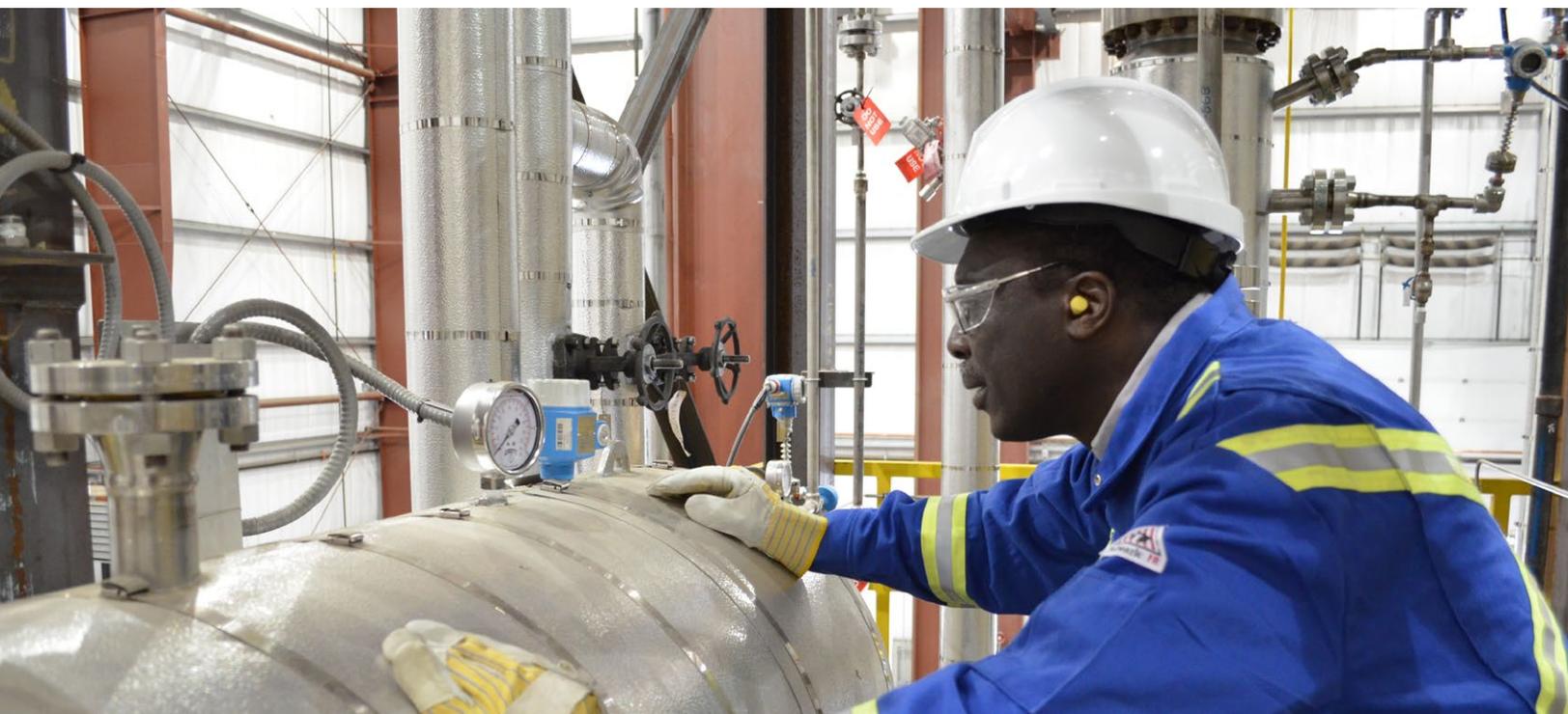
¹ Emissions Reduction Alberta (ERA) is a registered tradename of the Climate Change and Emissions Management (CCEMC) Corporation.

OBJECTIVES

The TRM seeks to:

- 1. Define pathways, opportunities and barriers to allow Alberta to thrive in a low carbon future through investment in innovation and technology. This will allow ERA to:**
 - ▷ Invest in technologies that contribute to our climate and energy vision of the future.
 - ▷ Identify opportunities for Alberta to demonstrate climate change leadership through high impact investments.
 - ▷ Demonstrate the value of directing public funds toward innovation and technology and provide a clear line of sight between funding and outcomes.
 - ▷ Invest in solutions that align with Alberta's needs and priorities.
 - ▷ Leverage Alberta's assets to attract world-class innovators and technologies.
 - ▷ Contribute to Alberta's economic prosperity and diversification by accelerating successful clean technologies and businesses.
- 2. Map the potential tactical options for delivering solutions, providing:**
 - ▷ Aligned and coordinated strategies to maximize outcomes.
 - ▷ A clearer understanding of ERA's responsibilities and accountabilities in the innovation system.
- 3. Identify milestones and deliverables, including:**
 - ▷ Measurable benchmarks and opportunities for emissions reductions as we work toward achieving economic benefits and high-quality employment opportunities.
 - ▷ Reporting of environmental and economic performance against identified targets.
 - ▷ Mechanisms to communicate and demonstrate progress.

Image: Enkern Biofuels facility in Edmonton



TRM AREAS OF FOCUS

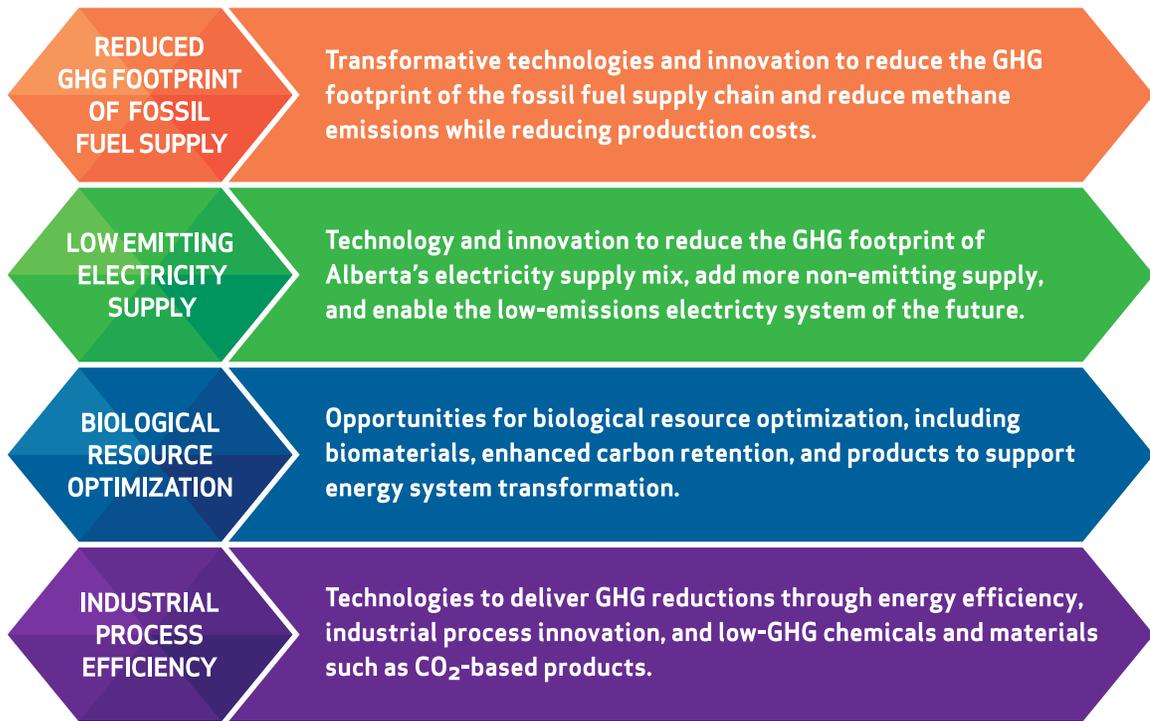


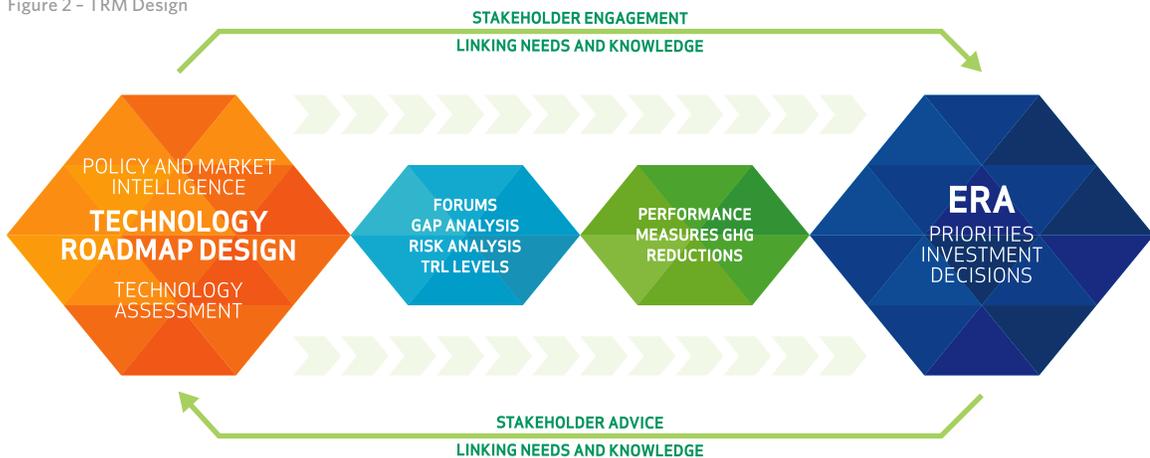
Figure 1 - TRM Areas of Focus

The TRM identifies four strategic investment areas of focus to achieve the TRM's objectives. The areas of focus are summarized in Figure 1 above and are described in detail beginning on page 12.

CONTINUOUS IMPROVEMENT

The TRM is a living document and is part of a continuous process designed to support ERA as a flexible and nimble organization that can adjust to new information, challenges, and opportunities. The TRM assists multiple organizations that represent ERA's stakeholders to focus on common goals, technology pathways, priorities, and defined implementation timeframes. An illustration for the design of the TRM is provided in Figure 2.

Figure 2 - TRM Design



In January 2018, ERA engaged the Energy Futures Lab (EFL) and its Fellowship to review the TRM. This review leveraged the expertise in the EFL Fellowship to:

- ▶ Analyze the four investment areas of focus described in the current TRM and provide a summary of ideas and recommendations to take them to the next step (i.e. “a deeper dive”) in terms of defining pathways and success.
- ▶ Provide overall advice and insights for the next iteration of the TRM.

Key to the EFL’s review of the TRM was a “backcasting from the future” perspective that is central to the EFL’s work. While forecasting projects past trends into the future, backcasting starts with the end in mind, seeks to outline conditions for a successful future, and then uses this vision for the future as the starting point for planning.



1. **Begin with the end in mind.**
2. **Look back from the future to the present.**
3. **Move step by step toward the future.**

Figure 3 - Backcasting — What and Why

This version of the TRM includes the valuable input provided by the EFL Fellowship. Central to their advice was that the next version of the TRM help better clarify the question, “A Road Map to What?” by providing a more specific and compelling vision of Alberta’s lower carbon future. This vision can help paint a picture of the unique contributions Alberta can make in a low-carbon emissions future and illuminate options for technological pathways to get there.

Key Influences on Alberta's Climate and Innovation Priorities

NATIONAL COLLABORATION

Building on commitments and momentum from COP21 in Paris, the Government of Canada, the Provinces, and Territories developed a Pan-Canadian Framework for Clean Growth and Climate Change. Canada has committed to achieve a 30 per cent reduction in GHG emissions from 2030 levels and contribute to limiting the global temperature increase to less than 2 degrees Celsius above pre-industrial levels. Its proposed approach to combat climate change includes putting a price on carbon, working with international partners, and using evidence-based knowledge in decision making.

In 2015, the Federal Government signed on to "Mission Innovation", committing to double its clean energy research and development investment over five years. As a result, Canada will invest more than \$750 million per year in cleantech research and development.

Canada has committed to achieve a 30 per cent reduction in GHG emissions from 2030 levels and contribute to limiting the global temperature increase to less than 2 degrees Celsius above pre-industrial levels.

The leadership displayed by the Government of Alberta in developing a comprehensive climate change plan places the province in a strong position to work with the Federal Government to leverage investments not only in green infrastructure and the phase out of GHG emissions from coal-fired electricity production, but also in research and innovation to support climate change goals and targets. ERA's TRM can serve as a catalyst for broadening partnerships with organizations like Sustainable Development Technology Canada (SDTC) and federal departments like Natural Resources Canada (NRCan), while bringing together diverse stakeholders to directly promote and authenticate Alberta as a global leader on mitigating greenhouse gas emissions through technology innovation.

Alberta's industries also have a key role to play in delivering on our climate change and innovation objectives. The TRM can help ERA collaborate with industry partners, including large final emitters, technology developers, and organizations such as Canada's Oil Sands Innovation Alliance (COSIA), the Clean Resources Innovation Network (CRIN), and Energy Storage Canada, and ensure we are investing in solutions to the problems the market is demanding.

Image: Neil Camarta, director and founder, Enlighten Innovations (formerly Field Upgrading), Oil Sands Innovation Challenge recipient.



ALBERTA'S CLIMATE LEADERSHIP PLAN

Alberta's Climate Leadership Plan (CLP) represents important progress for the Province and is an example of aggressive actions in support of Canada's obligation to meet GHG emissions reduction targets. Alberta has earned a great deal of credibility for developing a comprehensive climate change plan, and also for the process of bringing together diverse stakeholders to strongly support the plan, including the Alberta business community, the aboriginal and environmental community, academic institutions, and the public.

The CLP is aligned with GHG mitigation priorities for Canada and North America, as well as with international agreements, and provides a mix of policy tools with the potential to deliver significant GHG reductions. Meeting global targets will require ambitious and comprehensive programs of GHG mitigation options for Alberta and Canada for the period from 2030 to 2050. To realize the most ambitious targets, the TRM must establish technology development and demonstration priorities that support the CLP in the 2018 to 2030 timeframe, and position Alberta to achieve emissions reductions beyond 2030.

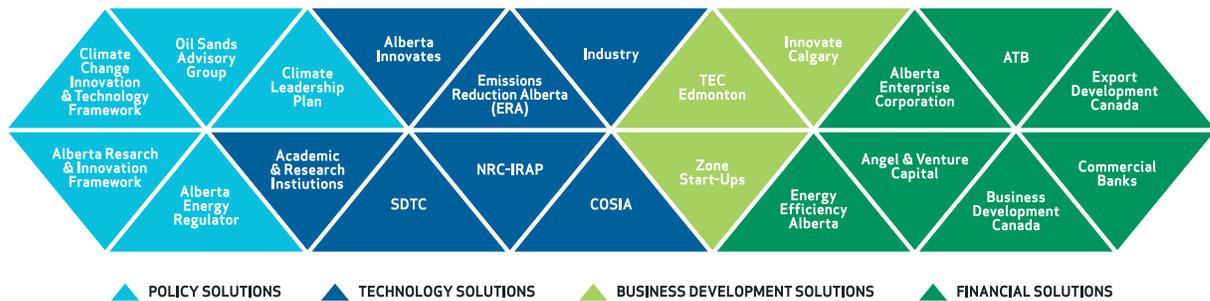


Figure 4 - Alberta's evolving innovation system

ALBERTA'S EVOLVING CLIMATE AND INNOVATION SYSTEM

Alberta's innovation system is evolving (see Figure 4), with climate change emerging as a key system priority. To support diversification, education, training, climate change action, and job creation, ERA works in close alignment with the ever-evolving innovation system and the several guiding and complementary strategies being developed by government departments. The TRM is part of an ongoing dialogue and feedback loop to ensure a common and mutually supportive approach across key components of the system, including:

- ▶ **The Alberta Climate Change Office (ACCO)**, which is mandated to coordinate the implementation of the CLP. ERA consults with the ACCO and Alberta policy makers to ensure that there is a good understanding of their needs in implementing the CLP and shaping the next phase of mitigation options. ERA can also be a key interface point to provide advice to ACCO relating to potential opportunities for innovation to play key roles, and for policy to support rapid adoption of novel solutions.
- ▶ **The Alberta Research and Innovation Framework (ARIF)**, which was developed by Economic Development and Trade (EDT) to provide shared outcomes and aspirational targets for provincially-supported research and innovation organizations. Its 2030 Innovation Targets were collaboratively developed with input from Alberta government departments, Alberta Innovates and ERA. The TRM can help delineate the technology pathways for helping to deliver on climate innovation and technology priorities and timeframes.
- ▶ **The Climate Technology Task Force**, which was created by government to lead stakeholder engagement and make recommendations on a Climate Change Innovation and Technology Framework (CCITF) to help guide Alberta's investments in climate change innovation and technology. ERA is a lead agency for investing to advance Alberta's climate change innovation goals and was one of numerous Alberta organizations who provided input to the Task Force.

- ▶ **The CCITF**, which was announced in December 2017 and serves as the overarching guide for the investment of funds from the pricing of carbon emissions for innovation and clean technology. The CCITF supports investment of public dollars in clean innovation across a number of technology areas, including cleaner oil and gas development, low carbon electricity, green products and services, and sustainable waste management. ERA is responsible for Clean Technology Demonstration and Scale-Up within the CCITF. Overall, ERA areas of focus are well aligned with the market opportunities identified by the Framework (Figure 5).

Alberta's Lower Carbon Economy - Pathways to a Cleaner Future

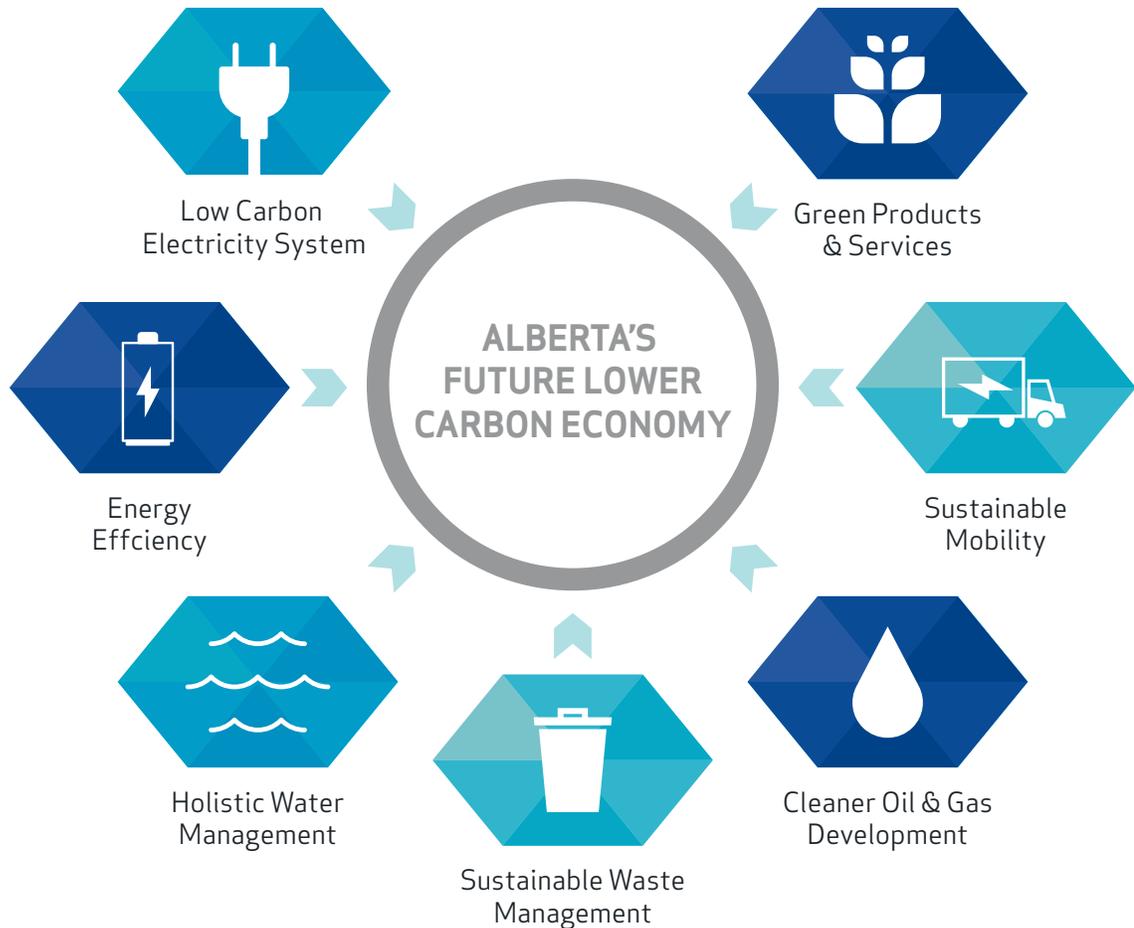


Figure 5 - Potential Clean Technology Sector Opportunity Areas from the CCITF

- ▶ **The Oil Sands Advisory Group (OSAG)**, which was established by Government to examine issues on implementation of the province's new 100 MT per year emissions cap on oil sands greenhouse gas emissions. The OSAG offered advice on how revenues from the carbon levy can be invested to reduce per-barrel emissions from the sector. ERA provided input to the OSAG regarding specific opportunities in the oil sands that can be addressed by innovation.
- ▶ **Energy Efficiency Alberta (EEA)**, which is a provincial agency that promotes and supports energy efficiency and community energy systems (including micro-generation and small-scale generation) for homes, businesses, communities and industry. An Energy Efficiency Advisory Panel was created to advise the government on the types of energy savings programs that EEA can start to deliver in the short and medium-term, as well as help set out a long-term vision. ERA and the TRM focus on distinct industrial energy efficiency themes that are complementary to those of EEA.

THE TECHNOLOGY IMPERATIVE

Under the CLP, the Alberta government has committed to taking significant action to reduce GHG emissions in the province. Alberta's GHG emissions profile (Figure 6) illustrates the sectors where GHG reductions will have maximum impact. The 2030 estimate of potential reductions that might be expected to be delivered under the CLP is shown in Figure 7.

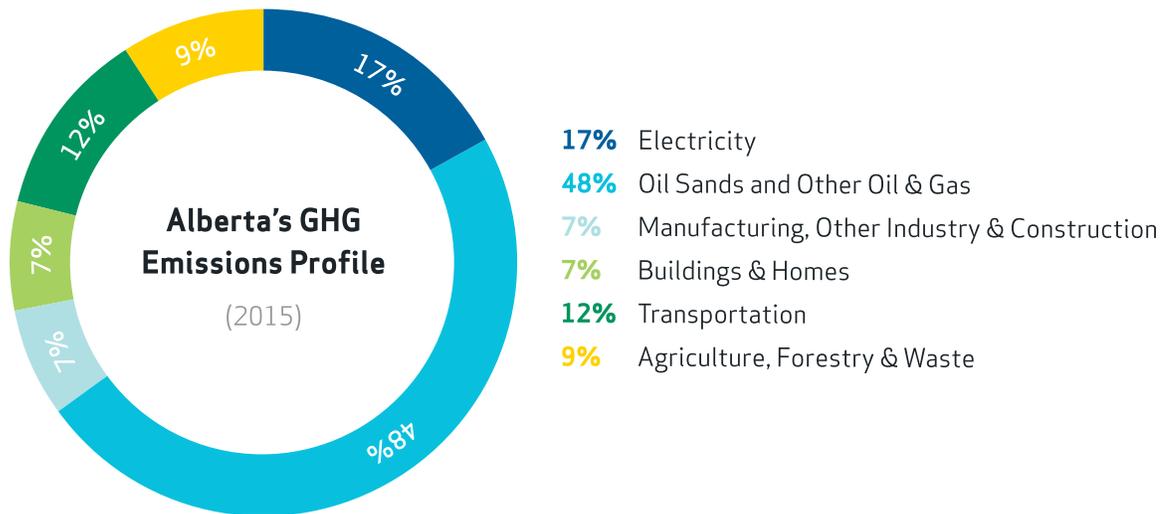
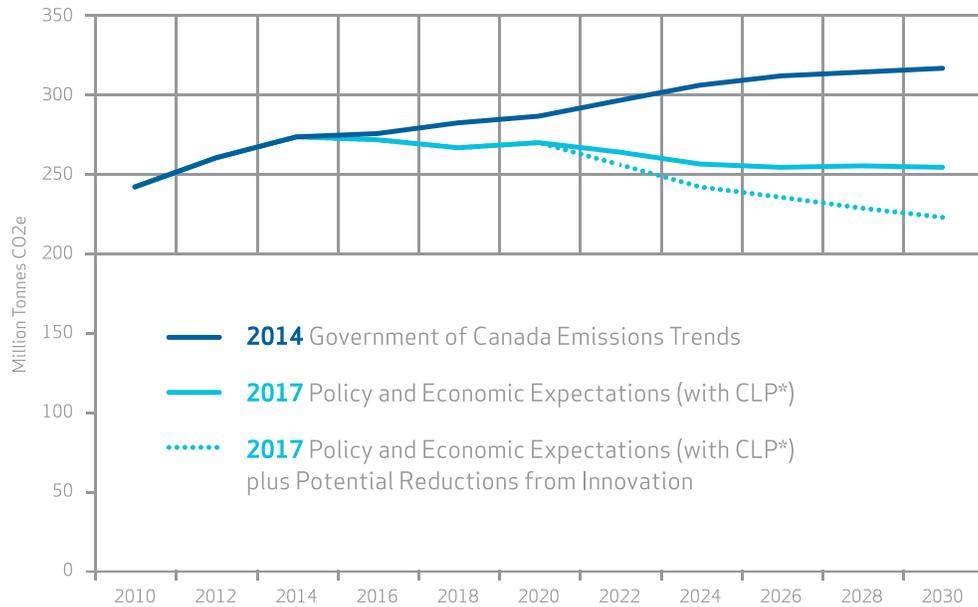


Figure 6 - Alberta's GHG Emissions Profile (2015)



* Includes Alberta’s Climate Leadership Plan and federal climate policies.

Data source: Environment and Climate Change Canada – National Inventory Report 1990 - 2015: Greenhouse Gas Sources and Sinks in Canada; Environment Canada – Emissions Trends 2014; ACCO Internal Analysis

Figure 7 – Estimated GHG Impacts of the CLP

Source: Climate Leadership Plan Progress Report 2016 - 2017

Alberta’s challenge is to deliver emission reductions while growing and diversifying the province’s economy. Achieving deep, longer term reductions requires that we identify the critical innovation pathways, challenges, and opportunities to achieve this target while supporting Alberta’s job creation and diversification imperative.

Regardless of the specific GHG emissions target, new technology must be part of the solution to achieving significant reductions. Achieving longer-term GHG targets requires new breakthrough technology options and investment in higher-risk, high-potential technology development.

Image: MEG Energy, Oil Sands Innovation Challenge recipient.



TRM Design and Focus

The TRM defines priority areas of focus for investment that will:

- ▶ **Achieve GHG reductions in multiple timeframes (2020 and 2030+).** Investment across multiple timescales is required to be successful in addressing the climate change challenge. Nearer-term GHG emissions reductions are typically achieved through widespread deployment of commercially available, or nearly available, technologies, at the highest technology readiness levels (see Figure 8).

Longer-term reductions require focused and sustained investment in breakthrough solutions beginning at earlier stages. Investment may involve higher technology risk but is potentially higher reward.

Under the newly announced CCITF, ERA is responsible for investment in clean technology demonstration and scale up. Other delivery agents in Alberta's innovation system, such as academia and Alberta Innovates, will be responsible for investments in earlier stage technologies. Going forward, we expect ERA's investments will largely focus on field-pilots, demonstration and first of kind deployment projects; (e.g., TRL 6 to 9); however, we will work with our partners in the system to ensure seamless hand-offs as technologies progress towards commercialization.



Figure 8 - Technology Readiness Levels

- ▶ **Identify industry need and market opportunity.** Investment is required in GHG reduction technologies that are bold, ambitious, and demanded by the market. The concept of directed innovation involves defining key strategic GHG reduction technology development outcomes, which are then broken down into a series of smaller steps or deliverables that in sum allow attainment of the bolder outcome. The key to defining and refining these GHG reduction initiatives is an understanding of what solutions are being demanded by the marketplace. Directed innovation helps to more clearly identify and define innovation challenges in the marketplace, so they can be more easily understood and solved by innovation providers.

For new technology to become commercialized, it must provide a solution that the market needs. ERA invests in solutions that tackle the problems Alberta must solve today, while also seeking out transformative technologies to address Alberta's largest GHG sources over the longer-term.

- ▶ **Build on Alberta's existing strengths and create new opportunities.** There is an opportunity to invest in GHG reduction technologies that will green Alberta's existing industries. This applies to sectors that represent historical areas of strength, such as our oil and gas sectors, as well new industries that support economic diversification, such as our growing renewable and bioenergy industries. By investing in these areas, ERA can create a more sustainable economy, create new markets, and encourage job and economic growth.

Breakthroughs may also originate in other jurisdictions then come to Alberta at a later stage. In part, this can be due to systemic barriers and lack of access to early capital for innovative/entrepreneurial companies. ERA investment can help reduce barriers to development and demonstration of innovative technologies and increase adoption of technologies that may initially emerge in other markets.

- ▶ **Guidance from Alberta's climate and innovation system.** The Alberta Forum of the Trottier Transformation Project was held in July 2016, and brought together technical experts from government, academia, the environmental community and industry representing the oil and gas, renewables and power sectors around goals. This included analyzing decarbonization pathways to guide decision makers on evidence-based options for mitigating climate change impacts and assessing the most important short-term and long-term GHG mitigation transformation options for Alberta. ERA investment areas of focus were informed in part by the Forum's pathways and are guided by Alberta's climate and innovation policy frameworks, including the ARIF, CCITF, and CLP.

ERA invests in solutions that tackle the problems Alberta must solve today, while also seeking out transformative technologies to address Alberta's largest GHG sources over the longer-term.

ERA TRM AREAS OF FOCUS

ERA's four investment areas of focus are summarized in the Tables on the pages that follow. The summaries reflect the 2018 input provided by the EFL Fellowship, in particular its advice on how to better clarify a "A Road Map to What?" by providing a clearer vision of Alberta's lower carbon future, both overall and for each of the four investment focus areas the TRM identifies. Given the importance of energy to the economy and culture of Alberta, this vision should paint a picture of the unique contributions our province can make in a low-carbon emissions future in a way that inspires confidence in Alberta's prosperity and helps illuminate options for technological pathways to get there.

FOCUS AREA 1 – REDUCED GHG FOOTPRINT OF FOSSIL FUEL SUPPLY

Possible ERA Investment: 30 – 50%

In Brief	Transformative technologies and innovation to reduce the GHG footprint of the fossil fuel supply chain and reduce methane emissions while reducing production costs.	
Rationale	<ul style="list-style-type: none"> ▶ Vast majority of GHGs emitted in Alberta and growing emissions. ▶ 100 MT cap on oil sands emissions and methane reduction targets. ▶ Costly to pilot novel technologies. ▶ Opportunity to capture and utilize carbon to derive value. 	
A Roadmap to What?	<ul style="list-style-type: none"> ▶ Alberta's hydrocarbons will remain in demand and competitive as a source of primary energy nationally and globally, resulting in ongoing commercial opportunities (e.g., the development of new exportable clean technologies) and royalty income for the province. ▶ Alberta will be a leading user and provider of cost-effective Carbon Capture, Utilization, and/or Sequestration (CCUS). ▶ Alberta's hydrocarbon production will be low GHG-intensity (e.g., no methane emissions, energy efficient, utilizes renewable energy inputs and / or coupling hydrocarbon use with CCUS). ▶ Alberta will offer a range of energy products derived from hydrocarbons, including non-GHG emitting energy products such as hydrogen and electricity, as well as non-energy and value-added products (e.g. bitumen beyond combustion). ▶ Alberta and its business community will be leaders in technology and expertise that have helped the oil and gas sector reduce GHGs. ▶ The polarization on energy and environment issues, specifically oil and gas, will be dramatically reduced. 	
Potential Technology Initiatives	<ul style="list-style-type: none"> ▶ Advanced recovery ▶ Fugitive emissions ▶ Partial upgrading 	<ul style="list-style-type: none"> ▶ Electricity oil sands integration ▶ Beyond combustion ▶ Carbon capture, utilization and storage
Beyond Technology	<ul style="list-style-type: none"> ▶ Requires a strong focus on capacity building, training and social/cultural innovation. 	

FOCUS AREA 2 – LOW EMITTING ELECTRICITY SUPPLY

Possible ERA Investment: 20 - 30%

In Brief	Technology and innovation to reduce the GHG footprint of Alberta's electricity supply mix, add more non-emitting supply, and enable the low-emissions electricity system of the future.
Rationale	<ul style="list-style-type: none"> ▶ Large portion of Alberta's GHG emissions. ▶ Zero coal-fired emissions and 30 per cent renewable energy targets. ▶ Need for non-emitting baseload supply and flexible capacity. ▶ Support for novel technologies that are not already commercial (e.g., conventional wind and solar). ▶ Opportunity to capture and utilize carbon to derive value and enable hydrocarbons as a solution for low emitting baseload.
A Roadmap to What?	<ul style="list-style-type: none"> ▶ Alberta's energy system will achieve net-zero emissions, enabled by low emitting baseload (e.g., cogeneration, geothermal) and flexible capacity solutions (e.g., storage, demand response). ▶ Alberta's no / low emitting baseload generators will use hydrogen from Alberta's oil and gas sector and / or oil and gas directly with CCUS. ▶ Alberta will make major advancements in deployment of geothermal energy, particularly connected to existing oil and gas infrastructure. ▶ Alberta's low-emitting electricity system will provide electricity for an increasingly electrified energy system (e.g., industrial processes, transportation).
Potential Technology Initiatives	<ul style="list-style-type: none"> ▶ Co-generation ▶ Advanced grid management technology ▶ Geothermal ▶ Non-conventional wind, solar, hydropower ▶ Storage ▶ Low-carbon electrification (e.g., transportation, industrial processes, etc.)
Beyond Technology	<ul style="list-style-type: none"> ▶ Requires a strong focus on the potential for digitization, other enabling technologies (e.g., artificial intelligence), and policies to match demand and supply.

FOCUS AREA 3 – BIOLOGICAL RESOURCE OPTIMIZATION

Possible ERA Investment: 10 - 15%

In Brief	Opportunities for biological resource optimization, including biomaterials, enhanced carbon retention, and products to support energy system transformation.
Rationale	<ul style="list-style-type: none"> ▶ Opportunity to build on and diversify Alberta's natural resource and agricultural strengths. ▶ Opportunity to minimize and derive value from waste. ▶ Opportunity for technologies that explore the best uses for the land (reforestation, forest and agricultural management), and biological resources. ▶ Opportunity to enhance carbon retention and sequestration in Alberta's natural biological systems. ▶ Bioenergy and bio-cleantech opportunities. ▶ Need for solutions to economically aggregate/transport bio-feedstock. ▶ Need for technologies to support improved GHG measurement, detection and quantification.
A Roadmap to What?	<ul style="list-style-type: none"> ▶ Forestry, agriculture, and natural lands will be managed as energy systems such that they sequester carbon, optimize food and wood production, recycle and clean water. ▶ Alberta will leverage its energy and agricultural expertise to develop a world-class biofuel industry. ▶ Waste from agricultural and forestry processes will be aggregated and allocated for use (no waste left on field or in forest). ▶ Alberta will pioneer innovative uses of agriculture to solve energy and climate challenges (e.g., growing willows as an energy crop and as a means of water purification).
Potential Technology Initiatives	<ul style="list-style-type: none"> <li style="width: 50%;">▶ Biofuels for electricity, transportation, etc. <li style="width: 50%;">▶ Carbon retention <li style="width: 50%;">▶ Bioproducts - materials <li style="width: 50%;">▶ N₂O and CH₄ emissions <li style="width: 50%;">▶ Bioenergy <li style="width: 50%;">▶ Waste management
Beyond Technology	<ul style="list-style-type: none"> ▶ Requires a stronger focus on aggregation and prioritized use of biomass to determine which use cases will provide the biggest emissions reduction and economic potential (e.g., biojet to reduce aviation emissions).

FOCUS AREA 4 – INDUSTRIAL PROCESS EFFICIENCY

Possible ERA Investment: 15 - 20%

In Brief	Technologies to deliver GHG reductions through energy efficiency, industrial process innovation, and low-GHG chemicals and materials such as CO ₂ -based products.
Rationale	<ul style="list-style-type: none"> ▶ Opportunity to reduce emissions while maintaining or increasing competitiveness of existing industries. ▶ Demonstration and deployment of more efficient processes at facility level delivers nearer-term GHG emissions reductions. ▶ Need for technology to address fugitive leaks from pumps, valves, pipes, and pneumatic devices. ▶ Opportunity to use a waste product (CO₂) as the feedstock for new industrial processes.
A Roadmap to What?	<ul style="list-style-type: none"> ▶ Alberta will be a leader in industrial ecology; industrial processes will be designed to maximize positive feedbacks from systems integration opportunities. ▶ Alberta will be a world leader in developing and applying leading edge digital tools for process optimization (e.g., artificial intelligence and machine learning). ▶ Alberta will lead in pioneering CO₂ transformation and utilization opportunities. ▶ Alberta will build a competitive advantage through investments in efficiency improvements.
Potential Technology Initiatives	<ul style="list-style-type: none"> ▶ Industrial efficiency ▶ Process improvements ▶ Low grade heat utilization ▶ Products of CO₂
Beyond Technology	<ul style="list-style-type: none"> ▶ Benefits from a stronger focus on capacity building for “industrial symbiosis” and circular economy, where one’s waste is another’s input, as a way to reduce emissions.

BALANCING THE PORTFOLIO

Given Alberta's current energy mix, it is not surprising that emissions from the combustion of fossil fuels account for approximately 90 per cent of the province's GHG emissions. The TRM's four strategic areas are, therefore, focused on innovation that will:

- ▶ Significantly reduce emissions from fossil fuel use in the electricity sector, in oil and gas production, refining and in heating applications (thermal energy load).
- ▶ Displace high emitting fossil fuels with renewables and other low emitting sources from the major sectors of Alberta's economy.
- ▶ Enable technologies that will likely be commercialized in the medium- to long-term including low-cost, efficient electrical storage, carbon capture and utilization, and non-combustion products of fossil fuels.
- ▶ Support development of new products that will be demanded in a low carbon future.

Considering Alberta's CLP, the amount of emissions emitted by various sectors, and the opportunity for reductions and technological advancement, a breakdown of ERA's investment portfolio by focus

area is provided in the tables. Most of ERA funding is directed to technology scale-up, field pilots, and first-of-kind demonstrations and deployments.

However, ERA's portfolio should consider balance not only with respect to areas of focus, but also in terms of time scale and development risks. Earlier stage or more disruptive technologies by nature often represent higher technology risk but potentially offer a long-term, game-changing reward. Later stage solutions may offer lower technology risk and nearer term reward; however, results are typically more incremental.

Earlier stage or more disruptive technologies by nature often represent higher technology risk but potentially offer a long-term, game-changing reward. Later stage solutions may offer lower technology risk and nearer term reward; however, results are typically more incremental.



As such, ERA attributes a portion of its investments across its portfolio to more disruptive and emergent technologies. This includes technologies with potential to be highly transformative. ERA works closely with the post-secondary system, Alberta Innovates, and other trusted partners to align and coordinate these efforts.

ERA also dedicates a small portion of its investments to piloting or demonstration of prospective system-level innovations that may shift the cost curve for broader penetration of key technologies. Such investments would enable proving out of alternative approaches to infrastructure or system configuration, such as next-generation smart grid/microgrid demonstrations.

BEYOND TECHNOLOGY

Although ERA's core business is seeking out and investing in technology solutions, funding the right technologies alone will not deliver the ambitious climate and innovation goals Alberta has established. Clean technologies face significant challenges on the pathway to commercialization, and addressing these challenges requires a complete solutions approach that goes beyond the technology, including smart financing and strong business models, and creating an effective and efficient environment where good policies and strong regulatory frameworks enable us to deliver results.

To advance technologies towards commercialization, ERA will play a role not only as a funder, but also in engaging in complementary strategies being developed by government, providing mentorship, and convening organizations that promote innovation in Alberta and across Canada. Suggestions and examples are provided from the EFL Fellowship for "beyond technology" opportunities to further advance solutions for each area of focus.

Image: Kathy Sendall, ERA Board Chair; Brian Vaasjo, President and CEO, Capital Power; Dan Wicklum, CEO, COSIA; Michael Crothers, Shell Canada President and Country Chair discuss 'What the Marketplace Wants' at SPARK 2017 in Edmonton.



Performance Measurement

The TRM will be deemed successful if it delivers on the purpose and objectives described in the first section of the document.

Due to the varying magnitudes of risk and reward associated with investment across timescales and TRLs, ERA will adapt its performance metrics across the TRL categories.

Figure 9 below illustrates the “opportunity radar” for technologies that Reduce the Footprint of Fossil Fuel Supply as an example of the evaluation process for new technologies that are represented by the TRM.

At the higher TRL levels ERA’s performance measures will be based on absolute GHG reductions (tonnes delivered), near-term GHG potential, and economic benefits such as jobs created, investment into the province, and GDP growth. At the lower TRL levels the success factors will be based on indicators such as TRL level advancement, success rate, estimates of potential impact, partner’s interest and investments (leverage). It should be noted that each of these points represent a basket of specific technologies, individual examples of which may deviate significantly in risk and development time from the notional distribution illustrated in Figure 9.

Opportunity Radar – Fossil Fuel Decarbonization

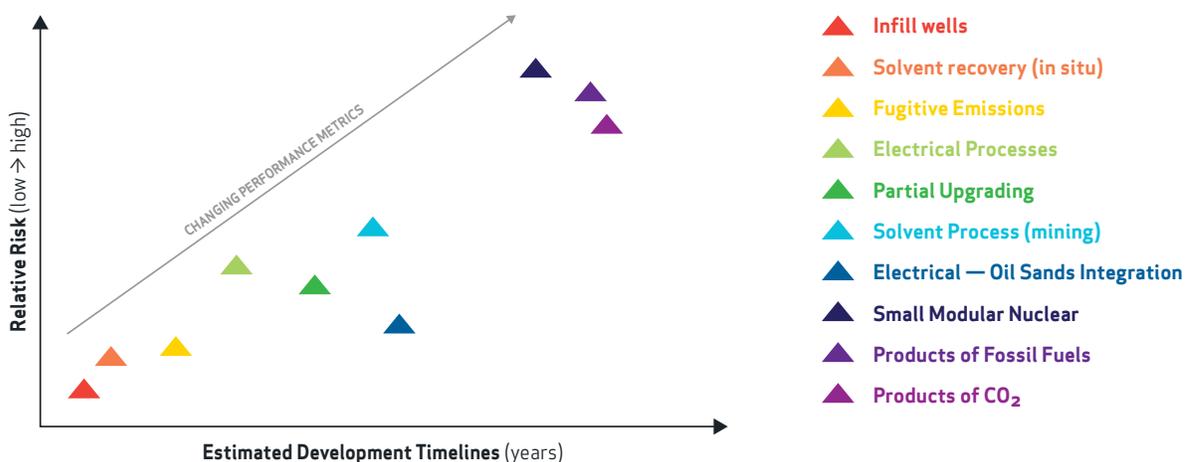


Figure 9 – Opportunity Radar – Fossil Fuel Decarbonization

While committed to delivering against a strong vision for the future, ERA is transparent and accountable to Albertans.

In addition to forward-looking performance measures used in selection of investment decisions, ERA relies upon a program of ongoing retrospective performance measures. This includes monitoring how closely actual investment performance tracks against projections used during project selection. This reporting will be done in the context that investment in innovation carries an intrinsic level of risk, and the role of this fund is to support de-risking prospective future contributors to the Alberta economy.

As such, impacts on emissions and economic activity, including leveraged investment, will be monitored during the course of the projects. Longer-term impacts following completion of the funded project will also be tracked. These include environmental impacts (domestic and international) as well as economic impacts, such as employment, attracted investment, domestic and export sales. Outcomes will then be compared and reported against forward-looking projections made at the time of investment.

COURSE CORRECTION

The unprecedented pace of technological change, as well as the breadth and the depth of many radical changes unleashed by both the new digital age and energy production technologies (e.g., fracking) represent major uncertainties for the direction of innovation. At the same time, global and Canadian climate policies will continue to evolve rapidly and will likely become greater drivers for technological innovation and change.

To ensure that ERA has the best available information for investment decisions, the TRM process will explore opportunities to work with other organizations on **technology scouting** (e.g., Alberta Innovates, Sustainable Development Technology Canada, etc.), **market intelligence** (e.g., MaRS in the Cleantech sector), **policy leadership** (e.g., Alberta's Climate Change Office and Economic Development and Trade) and **process modeling to assess technology pathways** (e.g., University of Calgary; University of Alberta; Deep Decarbonization Pathways Project; and Energy Futures Lab).



TECHNOLOGY SCOUTING

- Alberta Innovates
- Sustainable Development Technology Canada

MARKET INTELLIGENCE

- MaRS

POLICY LEADERSHIP

- Alberta's Climate Change Office and Economic Development and Trade

PROCESS MODELING TO ASSESS TECHNOLOGY PATHWAYS

- University of Calgary
- University of Alberta
- Deep Decarbonization Pathways Project
- Energy Futures Lab

Recommendation and Next Steps

The process for decision making on the GHG mitigation options and the understanding of how such mitigation programs can be implemented is complex. While the TRM ultimately belongs to ERA and will be used first and foremost to guide its investment decisions, it is important to continuously engage with others within the innovation ecosystem in Alberta and Canada. ERA will continue to seek advice on and validate the priorities and directions of the TRM, to ensure that key stakeholders are familiar with ERA's renewed mandate, and demonstrate that ERA is driven by a compelling vision based upon the principles of innovation, integration and collaboration. It is also important to stress that ERA's TRM and innovation pathways will help chart a course toward investment in innovative solutions that reduce GHG emissions while growing a diversified economy in a low carbon world.

To address these needs and ensure the TRM remains current, ERA will regularly engage with ERA Board members, government and its agencies, industry, environmental groups and technology experts to:

- ▶ Define the specific technologies supporting low GHG pathways and their timeframes, assess the trade-offs associated with alternative pathways and identify/validate the gaps and barriers that need to be addressed and, in general, the directions of the TRM.
- ▶ Continually consider the evolving business model, portfolio approach and the sequencing of calls for proposals to maximize delivery of GHG emission reductions.
- ▶ Seek advice on how ERA defines success in order to assist in developing and refining performance measures for ERA direction and investments.
- ▶ Identify ways in which greater impact might be achieved through bi-directional influence and synergies between/among organizations. For example, seeking to ensure that regulatory and/or procurement policies are responsive to positive results from ERA projects.

Image: MEG Energy, Oil Sands Innovation Challenge recipient.



THANK YOU

To our dedicated stakeholders for input and insights that supported the creation of the Technology Roadmap.

