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EMISSIONS REDUCTION ALBERTA

TECHNOLOGY ROADMAP

Alberta

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MESSAGE FROM THE CEO

The need for innovative technology solutions to achieve both economic prosperity and deep greenhouse gas (GHG) emissions reductions has never been greater. In 2016, Emissions Reduction Alberta (ERA) developed the first edition of this Technology Roadmap (TRM) to outline the strategic direction for our investments. Now, 8-years later, our team embarked on the research and engagement required to prepare the Fifth Edition.

In this latest edition, you will read about the global context—the geopolitical, economic, and policy shifts—that are impacting how ERA approaches its investments to create the right mix of short-, medium-, and long-term technologies to help Alberta realize its environmental and economic goals and support Canadian emissions reduction targets.

These international and national context developments reinforce four key points:

1. The transformation and evolving markets in our global energy systems remains uncertain, challenging, and disruptive. This requires us to remain nimble, monitoring, and reframing our portfolio for relevance
2. There are many different pathways to reduce our emissions and achieve carbon neutrality and we need to de-risk as many as possible
3. The need for innovative technology solutions to achieve both economic prosperity and deep emissions reduction has never been more urgent
4. The opportunities for Alberta to make a global impact are abundant.

In Alberta, we already have game-changing emissions-reducing technologies in various stages of development. Our goal is to have a range of more technologies deployed in market as quickly as possible. For this reason, after significant stakeholder consultations, we have established new objectives for our TRM while maintaining a focus on five cross-cutting technology areas. Importantly, the five areas are:

- Positioned to avoid a "single pathway" approach, based on the premise that solutions from all five areas will be necessary and valuable in any future carbon neutral scenario
- Expected to have the greatest potential impact on Alberta's GHG emissions and economy, as well as the most relevance to ERA's mandate
- Aligned with the Government of Alberta's Emissions Reduction and Energy Development (ERED) Plan
- Designed to help us reach provincial, national, and global environmental and energy development goals.

The second significant change you will see in this TRM is how we have reframed the emissions challenge in each area based on technology disruption.

ERA is proud to play a key role helping Alberta reduce its emissions, and our TRM is a valuable tool and reference document for Alberta's innovation system. The Roadmap is an important complement to ERA's Business Plan, which lays out the expected annual investments by ERA to ensure Alberta has a balanced portfolio of technologies. I trust you will find the TRM both interesting and inspiring.

JUSTIN RIEMER

CEO, EMISSIONS REDUCTION ALBERTA

INTRODUCTION

ABOUT TIER AND ERA

Alberta became the first jurisdiction in North America to implement an industrial carbon pricing and emissions trading system in 2007. The carbon levy is presently regulated under the Alberta Government's Technology Innovation and Emissions Reduction (TIER) Regulation, the core policy for industrial GHG reductions under Alberta's broader ERED Plan. TIER drives industrial operators to find innovative ways to reduce emissions and invest in clean technology to stay competitive and save money.

ERA was created in 2009 to invest the funds acquired through Alberta's industrial carbon levy. ERA receives a portion of the proceeds from TIER through a Grant Agreement with the Government of Alberta and has a mandate to responsibly invest these funds into the development and demonstration of novel technologies that reduce GHG's and strengthen the competitiveness of industries in Alberta. To deliver impact, ERA relies upon a competitive, transparent, efficient, and outcomes-focused model guided by an evidence-driven technology investment strategy.

ERA constantly evaluates its strategy and programming to align with the Alberta government's priorities. The combination of regulatory pull created by TIER and the technology push supported via ERA's investment of TIER funds creates a powerful incentive to accelerate technology development and implementation in Alberta.

TRM OVERVIEW

PURPOSE

ERA's TRM guides the organization's overall technology strategy, informing business planning, program design, and investment decisions. The TRM underpins ERA's efforts to support and advance a comprehensive roster of pre-commercial and commercial-ready technologies and solutions, working towards a vision where a broad suite of technology solutions are de-risked in support of public- and private-sector efforts to reduce emissions and enhance the economy. The TRM identifies the key opportunity areas where ERA's unique mandate and model can achieve the greatest impact, and aligns ERA's efforts within the context of the ERED Plan and the broader environment and innovation ecosystem in Alberta.

In developing the TRM, ERA's own technology experts engaged with a wide array of government, industry, investors, innovators, thought leaders, and subject matter experts to ensure that the technology areas align with the strongest opportunities for achieving a lower carbon future while creating economic opportunities for Albertans. Consulting with a broad range of stakeholders helps ERA establish a strategic vision for a balanced portfolio that accounts for uncertainty in the pace of technology development and the complexity of system transformations.

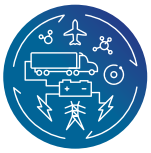
OBJECTIVES OF THE TRM

The TRM achieves its overarching purpose by delivering on the following objectives:

1. **Establish and promote a vision for Alberta as a leading jurisdiction for the development and deployment of emissions-reducing technologies to:**
    - Attract ideas, talent, and investment to the province
    - Enable Alberta's businesses to access and invent world-leading technology solutions that will help them maintain global competitiveness, explore new business opportunities, and access export markets
    - Highlight how ERA's investments can contribute to a better future for Alberta and the world
    - Enhance global recognition of Alberta as a leader and a hub for emissions reduction technology innovation.
2. **Characterize the current state of play regarding emissions reduction opportunities and challenges in Alberta to:**
    - Recognize Alberta's unique needs and strengths in the context of GHG emissions and technology innovation
    - Identify the technology solutions necessary for Alberta to thrive in a carbon-neutral future and any barriers that hinder their adoption
    - Ensure ERA's investment strategy is responsive to the rapid pace of change, shifting trends, and emergent drivers locally and globally.
3. **Define the optimal focus for ERA's investments to:**
    - Ensure ERA's strategy is aligned and coordinated with its unique mandate and value proposition, market needs, and the interests of key stakeholders
    - Prioritize investment areas where TIER funds can be most effectively leveraged to achieve targeted outcomes
    - Harness the power of responsibly directing public funds toward innovation and technology
    - Ensure Albertans benefit from the health, social, affordability, and other advantages associated with the adoption of new technologies.
4. **Outline key guideposts, objectives, and metrics to:**
    - Ensure ERA's investments deliver meaningful outcomes relating to environmental and economic benefits over various timescales
    - Enable effective tracking, benchmarking, and reporting of outcomes to establish the key indicators of progress and success
    - Support thought leadership and outreach
    - Provide a clear line of sight between ERA funding and meaningful impact.

IN SUMMARY: TRM FOCUS AREAS

To achieve the TRM's objectives, ERA has identified five technology focus areas, which are summarized below, and described in detail beginning on page 16.

AREA	*DEFINITION*	*SHARE OF GO FORWARD INVESTMENT*
 **IMPROVED EFFICIENCY**	Technologies and practices to improve energy productivity, optimization, conservation, and management throughout the economy.	**15%-25%**
 **EMERGING ENERGY**	Production, distribution, storage, and delivery of clean energy carriers that eliminate emissions from energy use, including the energy systems and infrastructure that enable them.	**20%-30%**
 **INDUSTRIAL DECARBONIZATION**	Novel processes, practices, feedstocks, and energy sources to deliver step-change improvements in emissions performance for major emitting sectors; development of new low-emissions products and industries.	**25%-35%**
 **CIRCULAR ECONOMY**	Improving how materials and products are designed, produced, and managed to reduce embodied carbon, reduce or upcycle waste, optimize product/material use, extend product lifecycles, and improve end-of-life practices.	**10%-20%**
 **CARBON MANAGEMENT**	Natural and artificial technologies and practices to capture, convert, utilize, and permanently sequester carbon.	**15%-25%**

DEFINING THE ROADMAP

METHODOLOGY

The TRM is developed as part of a continuous process designed to support ERA as a flexible and nimble organization that can adjust to new information, challenges, opportunities, and uncertainties. Its development is driven by internal research, analysis of ERA's current investment portfolio, consultation with the Government of Alberta, and engagement with key experts and stakeholders.

To develop this edition, ERA reviewed findings and forecasts from leading analysts, think-tanks, and academic institutions, as well as flagship climate reports such as those published by the International Energy Agency, United Nations, and World Resources Institute. ERA also reviewed analysis of key geopolitical, economic, and market trends from reputable sources, including provincial, national, and global organizations. This primary research informed key changes and trends in the emissions, energy, and technology landscape since the 4th Edition was developed.

ERA continually conducts technology scouting to identify areas of interest and to generate insights from legacy funding proposals and project reporting compiled over ERA's 15 year history. These insights were used to supplement the external technology research that informs the foundation of the TRM.

Another component of the TRM development process is input from the Government of Alberta, industry leaders, technology developers, investors, ERA's Board of Directors, and other key stakeholders. As part of the process, ERA consulted with Government of Alberta officials who research, shape, and implement relevant policy to identify and enhance alignment. In particular, ERA has ensured the TRM is aligned to the Government of Alberta's ERED Plan.

Following initial research and content development, ERA held one-on-one and group engagement sessions with over 60 leaders from across a spectrum of industries, including agriculture, forestry, oil and gas, electricity, critical minerals, and manufacturing, as well as research partners in academia, non-governmental organizations, and others in the innovation ecosystem. The sessions were designed to solicit insights from participants on:

- Challenges stakeholders currently face as well as further change or disruption they are anticipating
- Global influences that can impact local technology development and deployment
- Stakeholders' plans to advance innovative technology
- ERA's proposed focus area changes and the technologies that need to be considered within each part of the portfolio.

Participants also shared their point of view on the most significant opportunities for Alberta technology development, the state of technology readiness, and the role ERA can play in achieving the most significant emissions reduction impact.

Once drafted, the TRM undergoes multiple iterations and is shared with relevant parties for further consultation and review. This helps validate the guideposts and pathways outlined by ERA, and ensures that Alberta's industries and their emissions challenges and opportunities are appropriately reflected in the document.

This edition reflects the thoughtful insights of key stakeholders and thought leaders from across Alberta, Canada, and beyond. ERA is grateful for their contribution.

CONTEXT AND CONSIDERATIONS

Alberta's pathways to achieving a carbon-neutral economy by 2050 are affected by a broad set of economic, social, environmental, and technical influences both locally and globally. These developments serve to inform ERA's direction for new investments in technology and innovation.

GLOBAL CONTEXT

GEOPOLITICAL DEVELOPMENTS

In the two years since the release of the Fourth Edition of the TRM, global energy markets have been in constant flux due to a series of global political and economic events. Several conflicts have had far-reaching implications and heightened the focus on energy security and supply. Across the United States (US), Europe (EU), the United Kingdom (UK), and other major economies, landmark clean energy legislation has catalyzed a pivotal shift in the energy transition. Governments are increasingly committed to promoting sustainable energy alternatives to reduce emissions and to lesson their reliance on imported energy. While the global economy rebounded from the pandemic-induced downturn, countries around the world have faced supply chain disruptions, geopolitical tensions, permitting delays, and inflation, which have impacted the costs to finance and operate clean technologies. Rising energy costs are among the most significant factors contributing to inflation, underscoring the need for growth in the supply of affordable and stable energy.

TRENDS IN INDUSTRY AND TECHNOLOGY

There has been a surge in industry and government activity in carbon capture, utilization, and storage (CCUS), hydrogen technologies, and small modular nuclear reactors (SMRs). The clean hydrogen sector is growing rapidly, driven by incentive policies especially in the UK, EU, and US where efforts to stimulate the hydrogen economy have encouraged investors to initiate several public and private sector hydrogen hub projects. Moving commercial projects to a final investment decision has proven challenging and further deployment needs material improvements in technology performance and economics.

Renewable energy generation and zero emissions vehicles are approaching cost parity with incumbent solutions and are consequently experiencing exponential growth in adoption. This represents the start of a new phase of investment in these now-bankable technologies toward full-scale adoption and deployment. A shift is occurring from technology and financing risk toward supply chain and geopolitical challenges. Supply chains are highly concentrated for several critical minerals and metals and are susceptible to shortages and disruptions. This is driving new recognition of the need for financing and investment in new technologies to diversify extraction, grow production capacity, secure supply chains, and reduce the environmental impacts of mineral production.

Electricity grids have emerged as a key lever for emissions reduction, but as increasing volumes of clean energy is brought online there is a greater need for investment in complementary clean firm generation options and longer-duration energy storage. This includes flow batteries, metal-air, compressed air, pumped hydro, and other energy storage. The potential benefits of artificial intelligence on industrial operations and energy systems are also increasingly being understood and many more digital solutions are emerging. A growing area of focus is the need to expand and improve transmission and distribution systems, which can involve applying novel technologies to upgrade current networks but also requires new infrastructure to be built out.

EMERGING TECHNOLOGY FINANCE AND CLIMATE REPORTING DISCLOSURE

Financing for clean energy and emissions reductions has reached record levels, but further growth is needed to ensure new commercial technologies have sufficient access to capital. Financing of technology development up to and beyond the critical 'first-of-a-kind' continues to represent a 'valley of death' through which all innovative technologies struggle to progress. Traditional finance is poorly suited to funding this stage of development given the inherent risks, uncertainties, and lack of awareness of technologies. Lenders will need to consider a more risk-based posture to allocate some of this needed capital to achieve emissions reduction goals. New technologies may also require new business models or entirely new markets, further underscoring the need for strategic investments and funding sources that recognise the unique nature of emerging technologies. In particular, patient capital such as government financing has been a key element in driving the development and commercial deployment of many emissions reduction solutions.

Socially responsible investing, also known as Environmental, Social, and Governance (ESG) investments is rapidly evolving. Standardization of sustainability reporting has advanced significantly over the past few years. The International Sustainability Standards Board released its disclosure standards in June 2023, and government compliance requirements have also been advancing. In addition, regulators around the world are addressing the issue of greenwashing, or falsely claiming environmental benefits. In Europe, funds labeled with sustainable or ESG-related terms may be compelled to divest assets or change their names to comply with new anti-greenwashing fund naming guidelines released in June 2024. In Canada, Bill C-59, which received Royal Assent in June 2024, outlines changes to the Competition Act's deceptive marketing practices provisions, particularly those related to environmental benefit claims. These regulations increase the scrutiny on industry disclosures.

INTERNATIONAL POLICY LANDSCAPE

The US, and to a lesser degree the UK and the EU, are among Alberta and Canada's largest trading partners. Market opportunities also exist in China, Japan, Korea, Latin America, and Africa. These global policy, economic, and technology developments are taken into consideration as they impact local emissions reduction trends in Alberta and influence ERA's perspectives on technology investments.

In the US, major climate-related laws passed by Congress in 2022, has led to previously unseen momentum in cleantech investment. The Inflation Reduction Act (IRA), Infrastructure Investment and Jobs Act, and Creating Helpful Incentives to Produce Semiconductors and Science Act include grants, loans and tax credits to incentivize investment of domestic clean energy manufacturing and technology projects. An upcoming US election in November 2024 may have an impact on these new policies.

China has set ambitious carbon goals to peak emissions by 2030 and achieve carbon neutrality by 2060 and has invested significantly to create new solar, wind, and nuclear energy capacity. In 2023, China's solar PV capacity matched the world's total in 2022, and its wind energy capacity grew by 66% year-on-year. Over the last five years, China added 11 GW of nuclear power, the most globally[1]. Its strong domestic manufacturing and government support for clean technologies underpin its clean energy investment. This has global ramifications as export of clean technologies from China is reducing prices and expanding access to these technologies worldwide and particularly in developing nations. Japan and Korea, two of Asia's most developed economies, aim to achieve carbon neutrality by 2050. Japan's government has pledged to increase renewable energy deployment throughout the country, tripling energy capacity while ending new construction on unabated coal power plants.[2] South Korea, on the other hand, attributes over 40% of its industrial emissions to steel production and must therefore work to reduce emissions in this hard-to-abate sector, while also pledging to phase out coal-fired power plants by 2040 and accelerating renewable energy production to 40% by 2035.[3]

Latin America and the Caribbean, with one of the world's cleanest electricity sectors, are expected to play a key role in the global energy transition. Renewables generate 60% of these region's electricity, twice the global average. These regions, rich in wind, solar, and bioenergy resources, are major exporters of biofuel and critical minerals for clean energy technologies, with around half of global reserves of lithium, and more than a third of copper and silver reserves. They have seen a surge in clean investments, with countries like Brazil and Chile developing long-term hydrogen and critical mineral strategies and launching pilot projects.[4]

1 U.S. Energy Information Administration. (2024, May). China continues rapid growth of nuclear power capacity. *Today in Energy.*

2 Government of Japan. (2024, January). Together for Action: Japan's Initiatives for Achieving the Common Goal of Net Zero by 2050. *Kizuna.*

3 Yu, Alan; Roh, Hyunwoo. (2025, July). South Korea Climate Action: A Moment for Elevated Ambition. *Center for American Progress.*

4 Cozzi et al. (2023, November). Latin America Energy Outlook, part of World Energy Outlook 2023. *International Energy Agency.*

CANADIAN CONTEXT

NATIONAL CLIMATE POLICY OVERVIEW

As a signatory to the Paris Agreement, Canada has pledged its Nationally Determined Contribution to reduce emissions by 40 to 45% below 2005 levels by 2030. Canada has also committed to achieve a net-zero economy by 2050 and this target is legislated in the *Canadian Net-Zero Emissions Accountability Act.*

In March 2022, the federal government released its 2030 Emissions Reduction Plan (ERP) that outlines Canada's roadmap to achieve its emissions reduction targets. The 2023 ERP Progress Report, which indicates Canada is making progress toward its 2030 target, is the first of three reports required under the Act[5]. Subsequent reports are required in 2025 and 2027. The national backstop price on carbon pollution, initially set at $20/t$CO_2$e in 2019, has risen to $80 in 2024 and is set to continue to increase by $15/t$CO_2$e/year to $170/t$CO_2$e/year in 2030.

The Government of Canada is advancing numerous policies, regulations, and incentives that supplement the foundational measures of the ERP and carbon pricing to reduce emissions. Focus areas of these policies include fuels, electricity, methane, zero emissions vehicles, and critical minerals. In many cases, the individual policies include specific targets intended to support Canada's broader emissions reduction targets and enable a shift to a lower carbon economy that includes a greater proportion of clean energy sources in the overall energy mix of the country.

INCENTIVES AND INVESTMENT IN CLEAN TECHNOLOGY

Federal budgets in 2022 and 2023, unveiled a portfolio of refundable investment tax credits (ITCs) to position Canada as a global leader in clean technology, including clean electricity, hydrogen, CCUS, and manufacturing.

- **The clean electricity ITC** supports investments in renewable and nuclear electricity generation activities including wind, solar, hydro, wave, tidal, nuclear (small and large) as well as abated natural gas coupled with carbon capture
- **The clean technology ITC** is a tax credit for investments in clean technologies
- **The clean technology manufacturing ITC** supports clean technology manufacturers and includes incentives for extraction, processing, and recycling of critical minerals
- **The clean hydrogen ITC** offers varying levels of support for hydrogen production projects based on the carbon intensity of the hydrogen produced
- **The carbon capture, utilization, and storage ITC** (CCUS ITC) is a tax credit for investments to capture point source CO_2 emissions and CO_2 directly from the air, which is then transported and stored or used in another industrial process

Despite these efforts, some of the ITC's lack technical guidance and still have a long runway to providing industries with certainty for project development.

In addition to tax incentives, the Public Sector Pension Investment Board is enabled to manage the assets of the Canada Growth Fund to deliver on its mandate of attracting private capital to invest in Canada's clean economy, including the use of carbon contracts. The Canada Infrastructure Bank will also invest at least $20 billion to support building major clean electricity and clean growth infrastructure projects.

The suite of incentives the federal government is implementing is intended to keep Canada competitive with incentive schemes such as the US's IRA. In part, because of these federal and additional provincial incentives, large final investment decisions for decarbonization projects in Alberta have been made by the likes of Dow, Air Products, Entropy, and others. The effectiveness of Canada's incentives at achieving this will emerge over the next few years as industry makes investment decisions on where to site large capital technology projects.

5 2023 Progress Report on the 2030 Emissions Reduction Plan. Government of Canada.

ALBERTA CONTEXT

Alberta demonstrated its commitment to a carbon-neutral economy by 2050 with the release of its ERED Plan[6]. As outlined in the plan, the Government of Alberta seeks to maintain energy security and position Alberta as a leader in emissions reductions, while attracting investment, working with Indigenous communities, and supporting jobs. Key measures include continued financial support for CCUS, scheduled increases in the TIER industrial carbon levy to $170 per tonne by 2030, and further tightening of methane regulations. ERA remains a key enabler of this plan and will play a crucial role in investing in clean technologies to support the government's ambition.

CCUS AND HYDROGEN

Alberta is a global leader in CCUS and since it remains a strategic priority for Alberta, the Government has introduced the Alberta Carbon Capture Incentive Program[7] to accelerate CCUS projects in the province. In 2020, Alberta's Recovery Plan and Natural Gas Vision and Strategy articulated an ambition to incorporate hydrogen into Alberta's current energy portfolio. Alberta's Hydrogen Roadmap is the action plan that integrates hydrogen with the province's existing energy system and propels Alberta into the global hydrogen economy[8]. Alberta is already Canada's largest conventional hydrogen producer and has set a goal of $30 billion in capital investment to expand production capacity for clean hydrogen from natural gas using carbon capture technologies. Hydrogen can reduce emissions across a number of sectors including electricity and transportation.

RENEWABLES AND NUCLEAR ENERGY

Investment in renewable energy in Alberta over the past few years has been the highest of any province or territory in Canada. Following the moratorium on approvals for new renewable projects in 2023, the province has introduced new guidance for developing renewable energy projects and is in the process of a market and regulatory update for the entire electricity sector. Renewable energy is expected to form an important part of Alberta's electricity generation mix and contribute to a stable electricity grid. The Government of Alberta has also demonstrated a strong interest in exploring the role that nuclear energy can play to reduce emissions in the oil sands and electricity sectors.

GEOTHERMAL

Alberta's Geothermal Resource Development Act (2020) established a regulatory regime for geothermal administered by the Alberta Energy Regulator to oversee responsible development of geothermal resources and related wells and facilities.

ELECTRICITY GRID

After years of relatively linear electricity load growth, numerous factors are now pointing toward sustained and significant increases in demand on Alberta's electricity grid. In addition to macroeconomic factors such as GDP, employment rates, and population trends, electricity demand is projected to surge due to new loads arising from the increased use of electric vehicles, hydrogen production, electrification, and new digital industries[9]. The need to accommodate this load growth while continuing to decarbonize the overall generation mix will require significant and sustained investment in new generation capacity from a range of technologies. New grid technologies, especially those that add or enhance transmission, distribution, and intertie capacity, will be essential to ensuring the grid enables affordable, secure, reliable, and equitable access to energy for all participants.

CRITICAL MINERALS

Alberta is taking important steps to create and grow the critical minerals and metals value chain to help meet increasing global demand. The regulation to modernize Alberta's approach to tenure for metallic and industrial minerals took effect on January 1, 2023. The Mineral Resource Development Act came into effect for brine-hosted mineral development on March 1, 2023, and for rock-hosted minerals on February 28, 2024. This Act establishes the Alberta Energy Regulator as the full life cycle regulator for minerals in Alberta.

6 Emissions Reduction and Energy Development Plan. Government of Alberta.

7 Alberta Carbon Capture Incentive Program. Government of Alberta.

8 Hydrogen Roadmap. Government of Alberta.

9 2024 Long-Term Outlook. Alberta Electric System Operator (AESO).

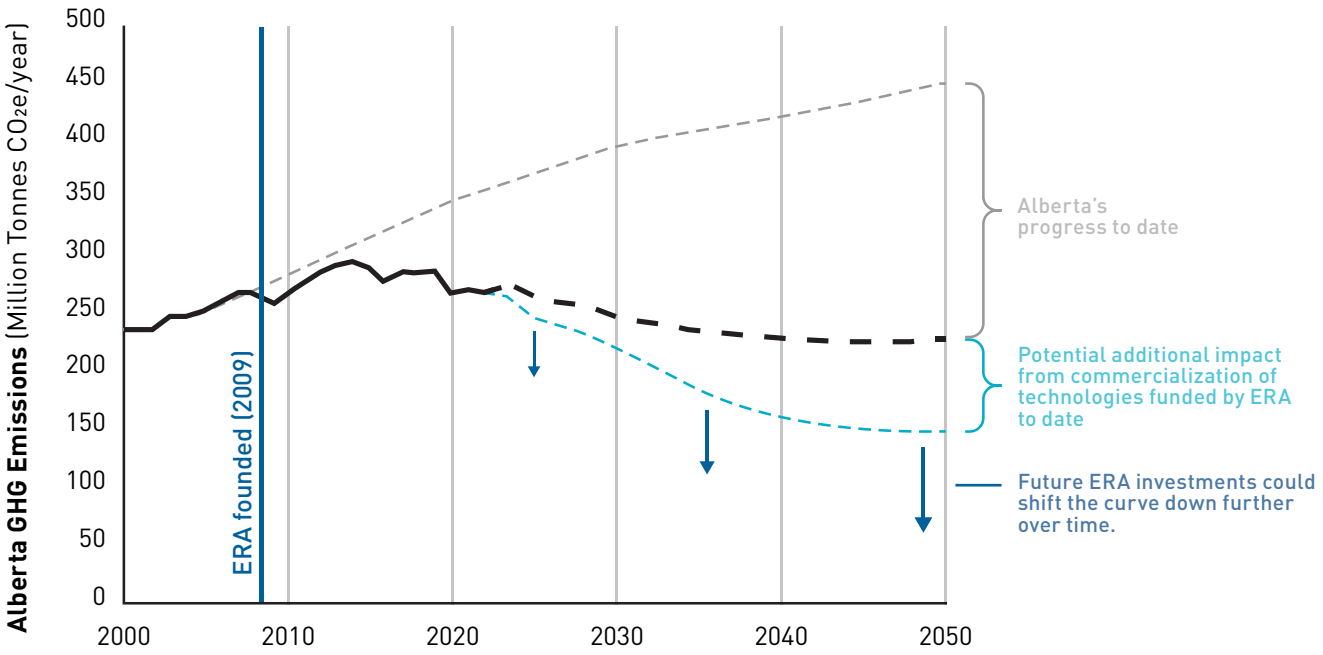
THE EMISSIONS CHALLENGE

Alberta's challenge, like most other jurisdictions, is to deliver emission reductions while growing and diversifying the province's economy. ERA's strategy is to focus on cross-cutting technology solutions, an approach that is informed by a thorough analysis of current emissions levels and trends. At the time of writing, the most recent full dataset for provincial and national GHG emissions is reflected in Canada's 2024 National Inventory Report (NIR), which includes data up to 2022.

In the years 2020-2022, Alberta's total GHG emissions stabilized at about 270 $MtCO_2e$ annually, a 6% reduction compared to pre-COVID emissions. However, emissions are still 7.5% above the 2005 emissions levels, which form the basis for Canada's nationally-binding emissions targets.

Compared to forecasts made at the time Alberta's industrial carbon pricing and emissions trading program was established, Alberta has made considerable progress on reducing emissions. Based on current economic and technology adoption projections, it is likely that Alberta's absolute GHG emissions have peaked and are now on a gradual downward trajectory. When potential additional impacts from commercialization of ERA-funded technologies are included, further emissions reductions can be expected, although this forecast depends on numerous assumptions and technoeconomic factors. There remains a need to accelerate the development and deployment of emissions reduction technologies to help Alberta achieve its emissions reduction ambitions as defined in the ERED Plan. Furthermore, the solutions that ERA invests in for Alberta can be exported globally to help deal with the collective emissions challenge.

ALBERTA GHG EMISSIONS *(MILLION TONNES CO_2e/year)*



Business As Usual: Forecast as of 2008 Alberta Climate Plan [12]

Business As Usual: forecast based on current policies and measures [13]

Actual historical emissions [11]

Potential additional impact from commercialization of technologies funded by ERA to date.

11 2024 National Inventory Report. Government of Canada.

12 Alberta's 2008 Climate Change Strategy. Government of Alberta (baseline adjusted to reflect inventory updates since 2008).

13 Canada's Energy Future Data Appendices. Canada Energy Regulator.

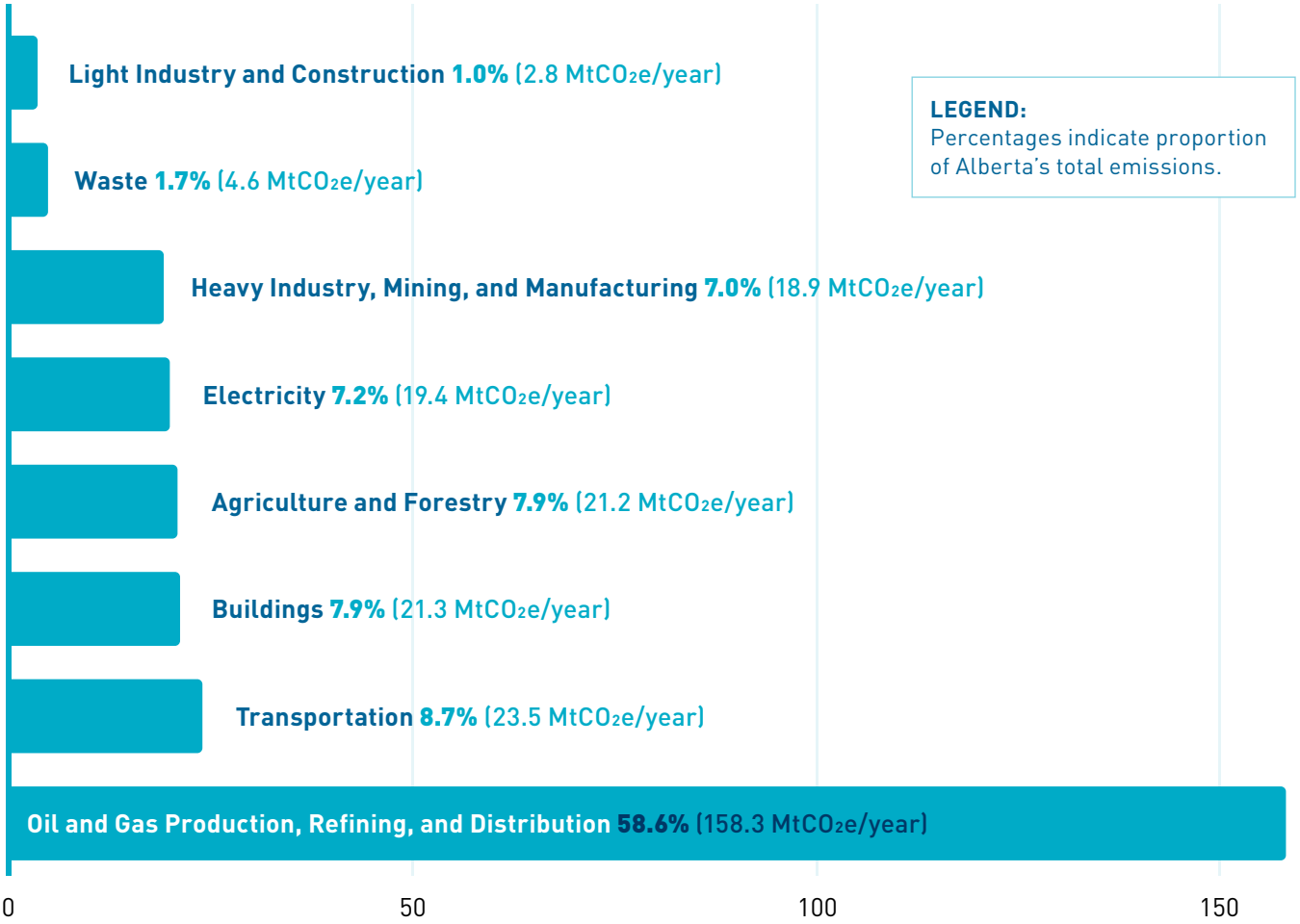
In Alberta, oil and gas production continues to be the largest source of emissions growth and the largest share (58%) of overall provincial emissions. Given that hydrocarbon production growth remains a provincial priority and emission intensity improvements to date have been outstripped by increases in production, emissions may continue to trend upwards unless transformative low-emissions intensity technologies and processes are de-risked and adopted at scale.

Emissions from the heavy industrial, light industrial, and manufacturing sectors account for 8% of emissions and have seen slow but stable growth. As these sectors are considered difficult-to-abate with conventional technologies, this suggests a significant need for next-generation technology innovation to achieve meaningful reductions in these sectors. Promising progress has been observed in the electricity sector which has experienced peak emissions and is now trending towards sustained annual reductions. Alberta's coal phase out and rapid addition of renewable electricity sources are the most significant contributors to this trend.

Emissions from buildings and transportation have grown moderately, balancing significant population growth with efficiency gains and fuel switching. However, faster adoption and retrofitting of new technologies is required to bend the emissions trajectory of these sectors downwards.

Agriculture, forestry, and waste emissions have also remained relatively stable, but have received lower emphasis than other sectors. Additional investment in technology solutions in these sectors is necessary, as they remain challenged in both measurement and monetization of carbon emissions and have typically had lower capacity to adopt emissions reduction solutions.

ALBERTA'S ANNUAL GHG EMISSIONS 2022 *(MtCO2e/year)*



ERA'S TECHNOLOGY FOCUS AREAS

Based on the context, influences, and considerations described previously, ERA has identified five complementary technology focus areas that define the opportunity space within which ERA will operate. The selection and definition of these areas was guided by a set of over-arching principles which include 1) the potential for technologies to deliver meaningful outcomes to Alberta, as defined by their Emissions Reduction Potential, Potential Economic Benefits, and Potential Additional benefits and 2) the opportunity for ERA funding to contribute to realization of those outcomes, including the Alberta Alignment, need for Technology Innovation, and Impact of ERA Funding. Ranking technologies according to these criteria led to the identification of five key focus areas by which to map the current portfolio as well as future investments. These criteria as well as the number of technology solutions in each area was then used to establish targets for future investments. Each of these factors is represented in the graphics on pages 15, 16, 18, 20, 22, and 24.

The resulting areas are deliberately broad, so as to span the full array of potential solutions for emissions reduction. They are also designed to have intentional overlap and synergy to promote cross-cutting opportunities and multipronged solutions. Within each area there are nearterm, medium-term, and long-term opportunities to reach carbon-neutrality goals. Importantly, the five areas are positioned to avoid a "single pathway" or "silver bullet" approach; rather, they are defined based on the premise that solutions from all five areas will be necessary and valuable in any future carbon neutral scenario. ERA will use these areas to guide its investments, steward its balanced portfolio, and set and report on key indicators of progress.

GUIDING PRINCIPLES FOR DEFINING TECHNOLOGY FOCUS AREAS

ERA's TRM is built upon seven key principles and insights that provide rationale and context for the technology focus areas in the strategy:

1. **Focusing on Alberta:** ERA's technology investment strategy will target opportunities for Alberta to leverage its strengths including natural resources, a highly-skilled workforce, and a strong innovation ecosystem. It will also account for local factors such as Alberta's unique industrial mix, policy landscape, and sector needs to focus on solutions with a strong market potential in the province. At the same time, it is imperative that the TRM recognize the distinction between areas where Alberta is or could become a leader versus those where it is more advantageous to learn from others as a fast follower. → **The focus areas are specifically relevant to Alberta and address the local context.**

2. **Reading the guideposts:** As a strategy to attract and develop leading solutions for emissions reductions, the TRM incorporates and reflects the most current, accurate, and reputable perspectives and insights regarding the opportunities and challenges in this space. The TRM will account for recent technological and geopolitical trends and influences while maintaining a long-term vision that is insulated from the "hype cycles" frequently associated with nascent technologies. Critically, the TRM will build upon the more than 15 years of learnings and insights gleaned from its existing portfolio of investments, ensuring that past results help inform future decisions. → **The focus areas reflect current technology trends and are based on best-available expert judgment and lessons learned from the portfolio.**

3. **Acting with the end in mind:** Recognizing that the investment, time, talent, and effort required to develop new technologies are all finite resources, the TRM seeks to identify the highest-leverage opportunities that are aligned with its long-term objectives. The TRM will focus on a broad suite of technology areas that will all be necessary and valuable in any future scenario where carbon neutrality is achieved, rather than specifying a particular pathway. → **The focus areas embrace the need to develop a robust "toolkit of solutions" rather than an "instruction manual" for reducing emissions and point the way towards achieving a positive vision for the future.**

4. **Targeting innovation and de-risking:** Extensive efforts have been made to develop and commercialize emissions reduction technologies in Alberta. Many solutions are now fully commercial, with further adoption driven by market forces and current policies. However, there is always the need to improve existing technologies, develop substitutes, create new markets, and de-risk new approaches. The technologies that will be needed to meet the needs of 2030, 2050, and beyond require investment today in order to move them towards commercialization. ERA's mandate focuses on new and innovative technology that can one day join the roster of commercialized, bankable solutions that are already being deployed. → **The focus areas align with ERA's mandate aimed at de-risking new and novel solutions to complement the array of already-commercial emissions reduction opportunities.**

5. **Taking a portfolio approach:** Investment in new technologies is inherently an exercise in managing uncertainty, balancing short-, medium-, and long-term opportunities, and weighing risk versus reward. The TRM recognizes the need to support solutions at various stages of maturity, with the objective of advancing a broad set of technologies toward full commercialization. Given the urgent nature of the emissions challenge, the TRM will seek to balance the need for "quick win" solutions that can deliver immediate emissions reductions by 2030, transition technologies to support reductions by 2050, and a pipeline of long-term transformative and "last-mile" solutions needed in 2050 and beyond. This approach, enabled by ERA's efficient and flexible business model, will result in a diverse portfolio that is balanced across timescales, technology readiness levels (TRLs), and technology categories. → **The focus areas are defined by a "portfolio of portfolios" approach, encompassing solutions across a diverse range of opportunities and allowing for multiple paths to success over various time horizons.**

6. **Aligning with market need and maximum leverage:** The TRM positions ERA to make the greatest impact in the identified areas of focus by identifying the most effective ways that ERA can support emissions reduction solutions. It recognizes that each sector and each technology have different needs when it comes to support and that de-risking technologies and commercial rollout can take various forms, including grants for pilot projects, support for pre-construction studies, and incentives for broad market adoption. In addition, the TRM accounts for the different risk appetites, capital intensities, and cost structures unique to each sector. → **The focus areas account for the diverse needs and challenges inherent to different sectors and technologies.**

7. **Recognizing the need for complete solutions and ecosystem alignment:** ERA is a key delivery agent for the Government of Alberta's ERED Plan. As a trusted and independent validator and supporter of new technologies, ERA has a critical role to play in convening technology customers, industry, policymakers, investors, and other stakeholders in the ecosystem to help ensure that new technologies receive the support they need. A focus on technology alone is not enough given the multitude of factors that can either inhibit or enable a technology to succeed. The TRM accounts for factors beyond technology, such as financing, policy, business models, talent, and dissemination of results that create the right conditions for success. → **The focus areas inform ERA's unique role as a convenor, responding to the need for holistic support and ecosystem alignment to drive successful commercialization of technologies.**

LOOKING BACK TO FORECAST AHEAD: LEARNING FROM OUR PORTFOLIO

Over the past 15 years, ERA has dedicated close to $1 billion toward nearly 300 projects aimed at reducing emissions and creating economic benefits. These projects are helping advance technologies that span Alberta's major industries.

The TRM is built as a forward-looking document, however it is informed and influenced by ERA's past and current portfolio of investments in two key ways. Firstly, the future balance of ERA's portfolio as defined by the TRM is necessarily an evolution and extension of the current portfolio; thus, it is critical for the TRM to account for what has come before. Secondly, each iteration of the TRM is an opportunity to reflect on the lessons learned from past investments and any particular gaps or high-leverage opportunities that have emerged from the existing portfolio. Over the years, the TRM areas of focus have oscillated between industries and technology areas, with this iteration continuing the focus on clusters of technologies that span sectors. ERA's focus has always been on supporting late-stage technology development, however not all technology development hurdles are solved by only providing de-risking capital.

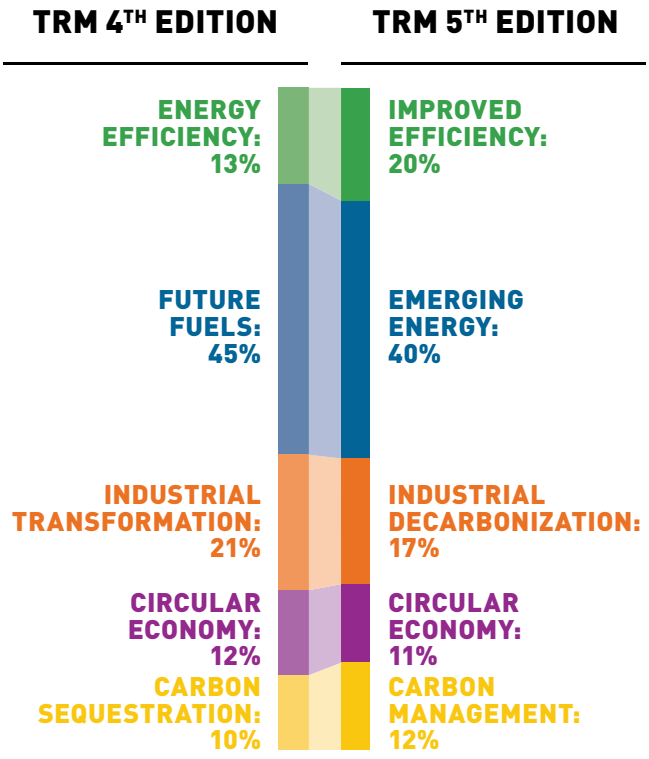
ERA has learned that some technologies require different configurations of support. For example, in 2022, ERA committed $40 million to funding pre-construction studies for facility-specific carbon capture opportunities. In addition to creating this unique funding opportunity, ERA worked with several other organizations and agencies such as the International CCS Knowledge Centre to disseminate information gathered on project progress. The knowledge acquired in these projects and others helps support government policies and incentives that lead to final investment decisions and contribute to technology adoption. Technologies that are near commercial present ERA the opportunity to support the low-hanging fruit that leads to short-term emissions reductions. Funding mechanisms in addition to ERA's non-dilutive grants, such as incentive programs and government regulations, will continue to accelerate market integration.

For other technology areas such as Emerging Energy, ERA's approach to project investments has shifted as technologies have matured. ERA funding helped de-risk some of the first renewable energy projects in Alberta, but as that market continues to commercially scale, ERA has refocused its efforts to supporting enabling infrastructure such as large-scale energy storage, grid services, and grid optimization. ERA's portfolio has signaled the need for energy innovation that increasingly requires end-to-end solutions that span the energy system.

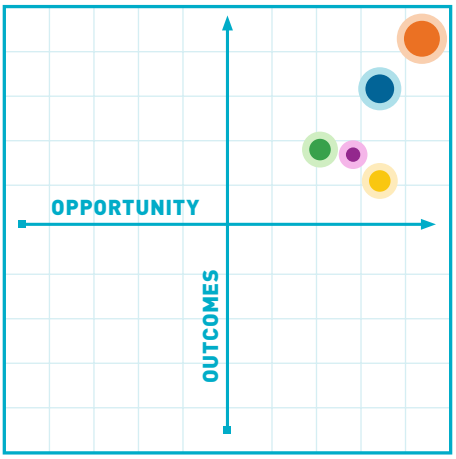
Finally, when ERA looks at its portfolio of investments, some of the most transformational opportunities are led by TIER-regulated facilities. Projects in this area have illustrated the benefit of continuing to ensure TIER funds circle back to these stakeholders, supporting the best projects that optimize Alberta's natural resource development and contribute to industry leadership and global competitiveness.

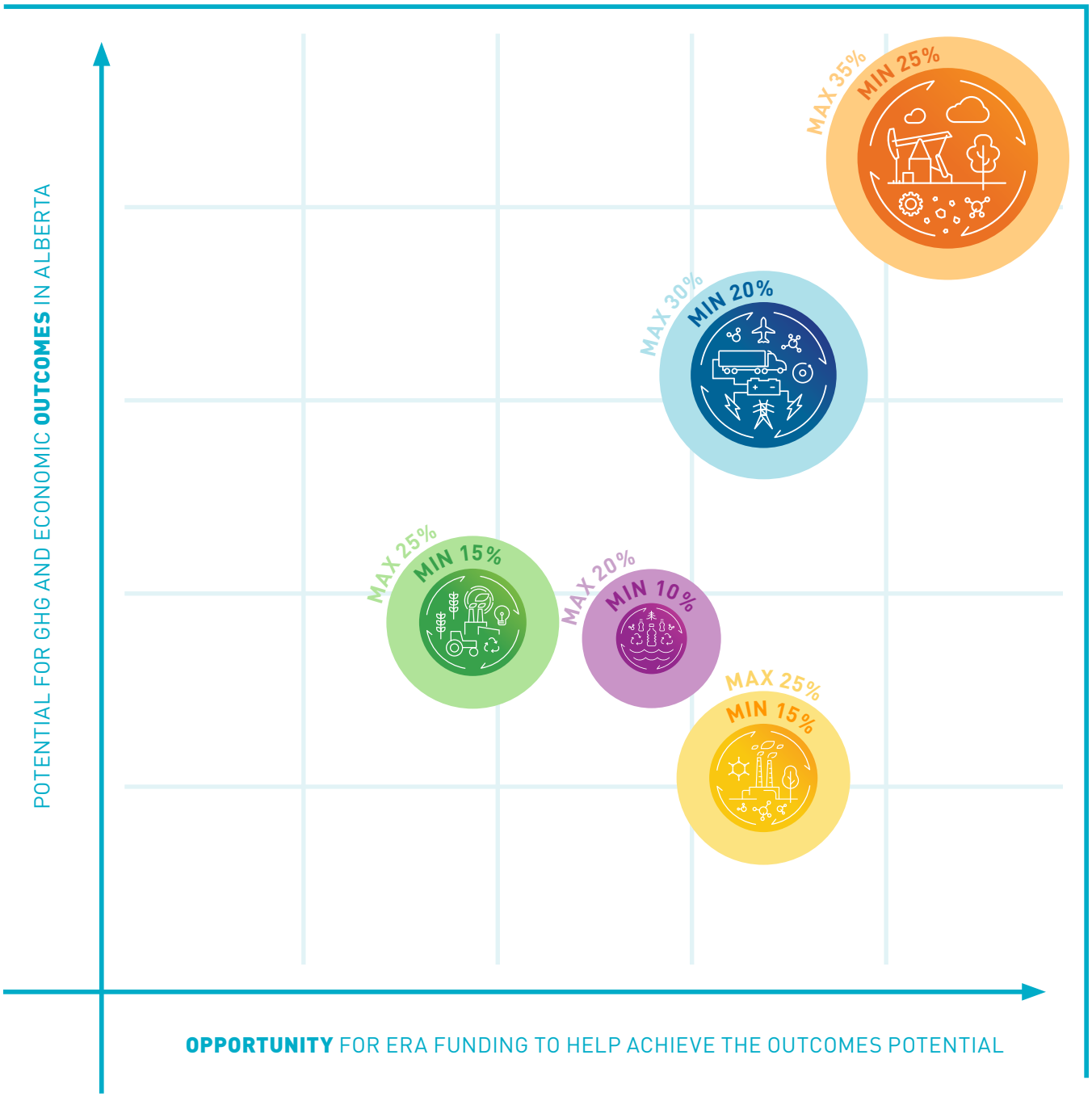
Looking ahead, ERA's approach to technology investment considers the balance of funded projects to date and how ERA's funding approach works in tandem with other organizations and funding mechanisms to advance projects to the next stage while signalling technology trends to watch.

BALANCE OF CURRENT PORTFOLIO BY INVESTMENT AREA



- INDUSTRIAL DECARBONIZATION
- CIRCULAR ECONOMY
- EMERGING ENERGY
- CARBON MANAGEMENT
- IMPROVED EFFICIENCY
- MIN SHARE OF GO FORWARD INVESTMENT
- MAX SHARE OF GO FORWARD INVESTMENT





IMPROVED EFFICIENCY

IN BRIEF

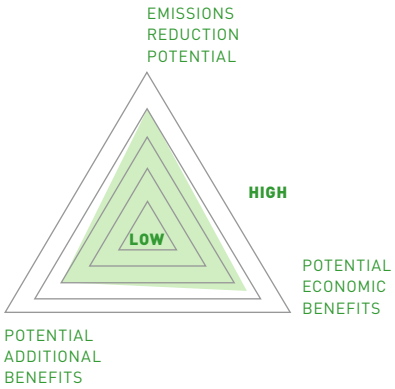
Technologies and practices to improve energy productivity, optimization, conservation, and management throughout the economy.

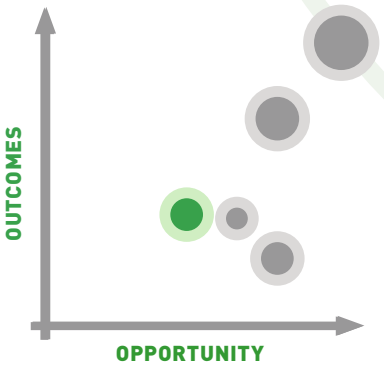
THE NEED

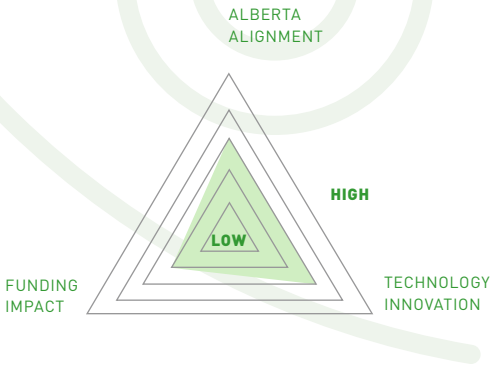
Energy use is a major driver of costs and emissions for consumers and businesses. Therefore, more effectively managing how energy is used and/or reducing wasted energy delivers a dual advantage of reducing emissions and improving economic competitiveness. Optimizing the efficiency of current systems and assets can deliver direct benefits while also freeing up energy, capital, and other resources for use in harder-to-abate areas.

THE ALBERTA CONTEXT

- Alberta's unique geography, population distribution, and climate mean that its buildings, transportation, and industries have high energy needs, translating to a greater opportunity to benefit from efficiency.
- Efficiency is a cross-cutting opportunity that can be applied to almost any sector. However, it has particularly significant potential for the buildings, commercial and industrial sectors.
- Alberta is a leading jurisdiction for methane management and abatement and has been the birthplace of numerous methane technologies with global export potential which may be leveraged into even greater impacts in the future.
- Alberta's large industrial base has significant opportunities to dramatically enhance the performance of existing facilities including numerous sources of waste heat.
- As a tool to enhance affordability and reliability, efficiency can be a positive force for mitigating recent inflationary pressures faced by energy consumers of all types.
- Alberta already hosts a burgeoning digital solutions sector, which is developing home-grown artificial intelligence and machine learning solutions that are positioned to deliver the next wave of efficiency improvements.







15-25%
SHARE OF GO-FORWARD INVESTMENT

A ROADMAP TO WHAT?

- Businesses and consumers are able to optimize operations and manage energy use, enhancing Alberta's competitiveness by reducing energy costs and improving affordability, reliability, resilience, and access.
- The profitability and performance of existing assets are improved, leading to an increase in equipment lifespan and decrease in stranded assets.
- Alberta's natural resource sectors achieve best-in-class performance on methane emissions, preserving market access, reducing wasted resources, and improving the lifecycle emissions intensity of energy products—and then exporting these methane solutions to the world.
- Alberta benefits from increased implementation and integration of digital and automation solutions, leading to rapid growth of the sector and development of capacity and export potential.
- Enhanced integration and optimization of energy systems, coupled with grid innovation and modernization technologies, are leveraged to reduce transmission, distribution, and other costs and alleviate congestion while enhancing affordability, reliability, resilience, and access for all users.

TECHNOLOGY EXAMPLES

- Digital solutions for automation and optimization.
- More efficient processes and practices in industry, agriculture, commercial, and manufacturing.
- Building improvements, including envelope upgrades, efficient heating, ventilation, and air conditioning (HVAC), and other equipment retrofits.
- Monitoring and management of energy use and emissions.
- Improved system design, including heat integration, waste heat recovery, and district energy.
- Detection, monitoring, management, and mitigation of methane emissions from the oil, gas, and mining sectors.
- Grid modernization, edge, and optimization solutions, including transmission and distribution system upgrades, non-wires solutions, demand response, digital grid optimization, virtual power plants, distributed energy resources, and others.

EMERGING ENERGY

IN BRIEF

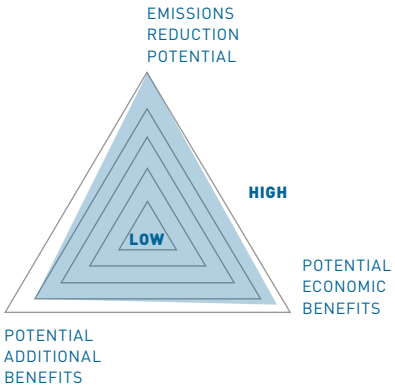
Production and adoption of clean energy carriers that reduce or eliminate emissions from energy use, and the infrastructure that enables them.

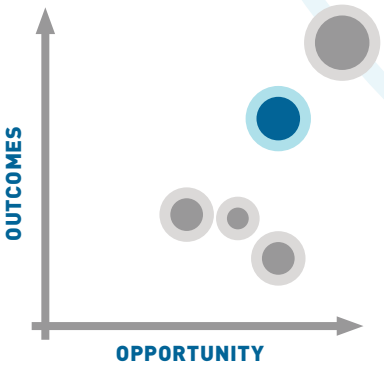
THE NEED

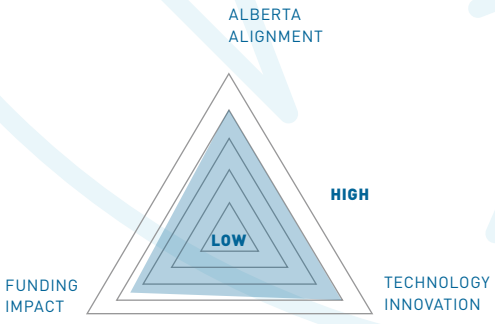
Production, distribution, storage, and delivery of clean energy carriers that eliminate emissions from energy use and mobility, including the energy systems and infrastructure that enable them.

THE ALBERTA CONTEXT

- Alberta's electricity system has successfully transitioned off coal, has the strongest wind and solar resource potential in Canada, and has access to low-cost natural gas. An emerging need for firm, dispatchable generation and clean grid services is providing continued motivation for innovation.
- Recent market developments have spurred rapid growth in deployment of energy storage and grid edge technologies, with significant future potential yet untapped.
- Alberta has a strong and growing biofuel/bioenergy industry, leveraging the combination of energy, agricultural, and forestry expertise.
- The province has developed a robust clean hydrogen strategy that is successfully establishing the conditions for a thriving hydrogen ecosystem.
- Preliminary investments in nuclear, hydrogen, and energy storage, as well as emission abatement of fossil fuel plants through technologies like CCS, have set the stage for a robust and cost-effective evolution of the grid.
- Alberta is home to all the required skillsets, talent, and supply chains for a thriving geothermal industry and is seeing a first wave of geothermal projects emerge.







20-30%
SHARE OF GO-FORWARD INVESTMENT

A ROADMAP TO WHAT?

- Alberta's deregulated electricity market remains a destination of choice for capital investment into new electricity technologies including renewable generation, energy storage, and distributed energy resources, enabling the export of clean power and meeting the demands from new loads such as electrification and data centers.
- A clean hydrogen ecosystem is catalyzed by existing and new industrial clusters to reduce Alberta's emissions and produce clean energy and products for export.
- Alberta capitalizes on its existing exploration, drilling, and thermal management expertise to become a world leader in geothermal energy technologies.
- Expanded use of clean or abated energy carriers across the economy enhances the health and air quality experienced by all Albertans.
- Next generation biofuels technologies are fully commercialized and used to generate significant value from waste and unconventional feedstocks, while bioenergy and waste-to-energy developments benefit from the maturation of CCUS technologies.
- Alberta combines its petrochemical and bio-industrial expertise to take a leading role in production of sustainable aviation fuel and other renewable fuels.
- Buildings and the transportation sector benefit from the adoption of clean energy carriers and devices while enhancing their integration with the broader energy system.
- Major industries in Alberta explore the potential for nuclear energy to provide everything from power generation to zero-emission industrial heat.

TECHNOLOGY EXAMPLES

- Advanced geothermal and nuclear energy for production of power and/or heat.
- Novel technologies for generation and storage of zero-carbon electricity, including agrivoltaics, low-head hydroelectricity, and other novel renewables.
- Energy storage and other solutions for grid services, firm power dispatch, ramp rate management, long duration energy storage, frequency response, and other applications.
- Integration of clean energy production and storage with buildings and industry.
- Infrastructure and enablers for electric and hydrogen electric vehicles.
- Transportation fleet transition to electric or hydrogen technologies for public transit, heavy duty, service, construction, and freight applications.
- Low emissions aviation solutions including hydrogen and sustainable aviation fuel.
- Next generation biofuels and bioenergy.

INDUSTRIAL DECARBONIZATION

IN BRIEF

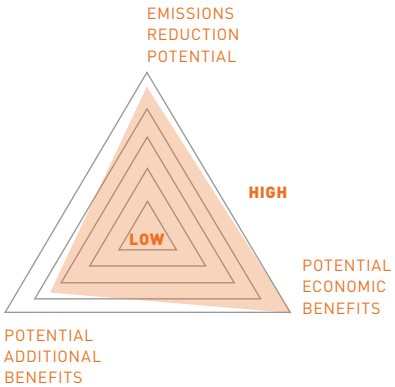
Novel processes, practices, and feedstocks to deliver step-change improvements in emissions performance for major emitting sectors, and the development of new low-emissions products and industries.

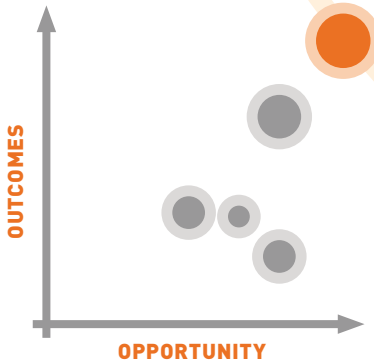
THE NEED

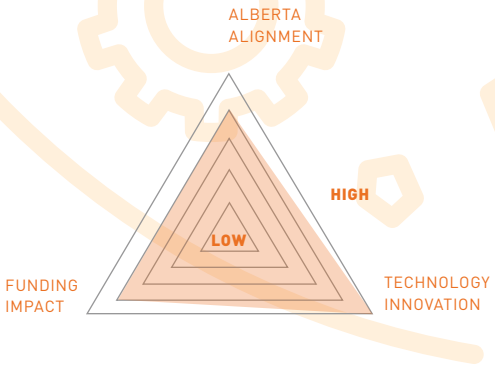
Alberta's major natural resource, agriculture, forestry, and manufacturing sectors are integral to the economy but often depend on energy- and emissions-intensive processes to deliver their products. Achieving meaningful emissions reductions in these sectors while enhancing their global competitiveness requires a transformative vision to adopt new technologies and processes with the potential to achieve step-changes in GHG performance. At the same time, development of entirely new, inherently lower-emissions sectors offers a pathway to grow the economy without adding to Alberta's GHG emissions inventory.

THE ALBERTA CONTEXT

- Oil and gas operators are exploring novel, low-emissions extraction and enhanced recovery processes such as solvents, steam additives, electromagnetic heating, and others.
- Alberta is home to several world-scale industrial clusters and has a wealth of engineering talent. These factors create fertile ground for development, piloting, and rapid adoption of new processes.
- Alberta's significant bitumen resources and engineering knowhow create new opportunities for high-value products without combustion emissions, such as bitumen-derived carbon fibres.
- There is growing recognition of the valuable minerals, such as lithium and vanadium, found in abundance in Alberta, but a technology push is needed to make their extraction viable.
- Critical industries and hard-to-abate sectors such as cement and fertilizer producers are investing in new material inputs, fuel switching, and process changes to reduce their GHG footprints.
- With a first wave of pilot projects, Alberta's industries are beginning to benefit from global technology progress on electrified heat including industrial heat pumps, electric boilers, and thermal energy storage.
- Alberta's strong agriculture and forestry sectors are poised to enhance their competitiveness by adopting best-in-class technology solutions, and can benefit from talent and solutions developed in other sectors.







25-35%
SHARE OF GO-FORWARD INVESTMENT

A ROADMAP TO WHAT?

- Alberta's oil and gas producers capitalize on new technologies to dramatically reduce emissions, enhance production cost competitiveness, mitigate environmental impacts, and maintain market access.
- Alberta's existing industrial clusters, talent, and access to clean feedstocks and affordable energy are leveraged to make Alberta a destination of choice for new investment and attraction of best-in-class solutions for the province.
- New chemistries, processes, and advanced manufacturing techniques enhance the competitiveness and productivity of major manufacturing sectors in the province while opening new business opportunities.
- Alberta's strengths in resource development, coupled with global market trends, enable Alberta to become a major producer and exporter of lithium, vanadium, carbon fibre, and other minerals and advanced materials.
- Natural sectors including agriculture, agrifood, and forestry adopt best in class technologies and practices, leading to greater market acceptance and new value streams while reducing environmental impacts.

TECHNOLOGY EXAMPLES

- Advanced extraction techniques for bitumen and other hydrocarbon resources.
- Novel products from bitumen, including hydrogen, carbon fibre, activated carbon, electrodes, and supercapacitors.
- Clean heat solutions including fuel switching, e-boilers, heat pumps, and thermal energy storage.
- Mitigation of non-CO_2 emissions from agriculture and forestry, including enteric methane, N20, and others.
- Extraction, processing, and refining of lithium and other critical minerals.
- Novel chemistries, feedstocks, and processes for manufacture of cement, fertilizer, plastics etc.
- Novel processes and practices for agriculture and forestry.

CIRCULAR ECONOMY

IN BRIEF

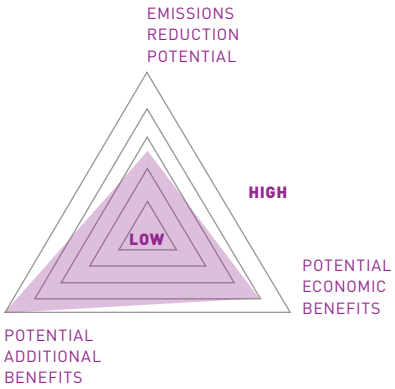
Improving how materials and products are designed, produced, and managed to reduce embodied carbon, reduce or upcycle waste, optimize product/material use, extend product lifecycles, and improve end-of-life practices.

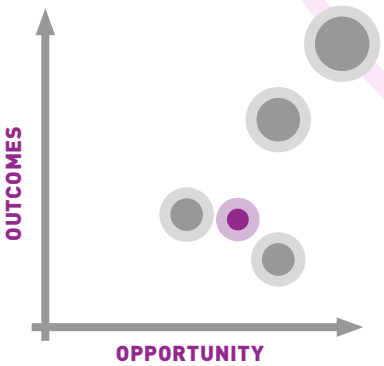
THE NEED

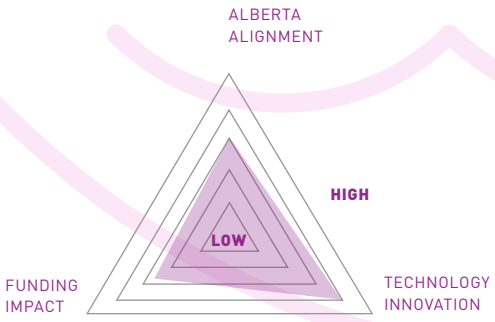
Beyond the GHG emissions associated with production, there are also significant emissions associated with the lifecycle, disposal, and wastage of products and materials such as construction materials, plastics, forest products, and food. Enhancing how products and materials are designed, used, re-used, recycled, and managed with the end of life in mind, has significant potential to reduce emissions while delivering important co-benefits such as reduced waste volumes, lower land and water impacts, lower overall costs, and displacement of demand for raw materials.

THE ALBERTA CONTEXT

- Alberta's strong forestry and agriculture sectors have unique and growing needs for waste management and are exploring opportunities to valorize and upcycle waste into new products.
- Alberta is a major producer of plastics and petrochemicals and has committed to becoming a circular plastics centre of excellence.
- Alberta's Extended Producer Responsibility Framework encourages producers to design plastics and other single-use products in a way that reduces their overall footprint, including novel ways to recycle and reuse material inputs.
- There is a strong legacy of anaerobic digestion and waste-to-biofuels trials in Alberta, however further technological advancement is needed to make these sectors viable.
- Bioproducts and other low-embodied-carbon materials are gaining recognition for their potential benefits but require further development and acceptance.
- Management, treatment, and waste reduction for water is a growing area of interest for sustainability and climate resilience.







10-20%
SHARE OF GO-FORWARD INVESTMENT

A ROADMAP TO WHAT?

- Agriculture, food, forestry, and industrial waste streams are significantly reduced, enhancing cost competitiveness and reducing environmental impacts.
- Novel waste-derived products offer new economic opportunities, transforming what is currently a significant cost for many sectors into new revenue streams.
- Alberta's plastics industry is recognized as a world leader in circularity and sustainability, ensuring ongoing market access and consumer acceptance.
- Optimization of product supply chains, lifecycles, and end-of-life treatment becomes standard practice. When single-use materials are used, their production requires fewer raw materials and has a lower energy and environmental footprint.
- Biogenic feedstocks, including upcycled waste, are used to displace higher-emissions feedstocks and reduce the demand for raw materials.
- Everyday products and infrastructure incorporate recycled or upcycled materials and have a lower embodied carbon footprint.
- Management of agriculture and food waste reduces emissions while enhancing food security and affordability.
- Oil and gas operators are able to effectively remediate contaminated soil, tailings, wells, and other affected sites, responsibly closing wellsites and returning land to productive or natural uses.
- Alberta's industries more effectively manage and remediate wastewater, reducing net impacts on Alberta's shared water resources and enhancing resilience.

TECHNOLOGY EXAMPLES

- Circular plastics including recycling via chemical, mechanical, or other means.
- Next generation technologies to process and upcycle municipal, agricultural and forestry wastes.
- Digital-enabled solutions for product design, lifecycle innovation, and tracking.
- Biogenic and/or waste-derived feedstocks for construction materials, petrochemicals, and other products.
- Enhanced industrial linkages whereby waste streams are converted to inputs, such as clinker substitutes from waste.
- Tailings, wastewater, and contaminated soil treatment and remediation solutions.
- Food waste reduction.

CARBON MANAGEMENT

IN BRIEF

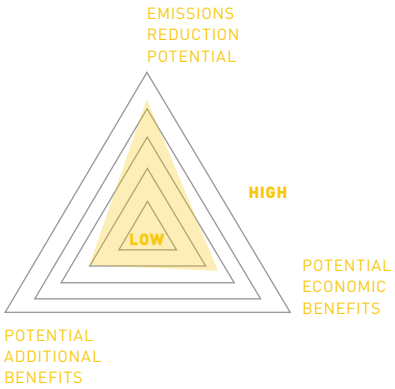
Natural and artificial technologies and practices to capture, convert, utilize, and permanently sequester carbon.

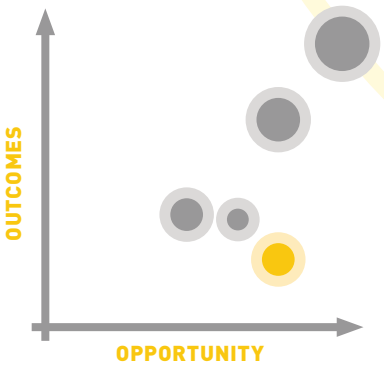
THE NEED

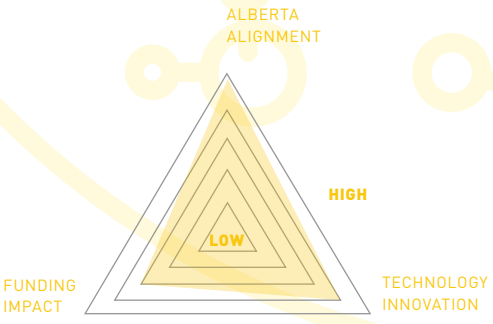
The need for enhanced carbon management as an option to mitigate or drawdown emissions remains, particularly where other abatement techniques are insufficient. This requires engineered solutions for point source or even diffuse carbon capture, and improving the way Alberta leverages natural systems to increase sequestration of carbon and mitigation of other emissions.

THE ALBERTA CONTEXT

- Alberta is already a world leader in carbon management, with a massive pore space resource, strong carbon hub strategy, and multiple operating CCS facilities such as Shell Quest, the Alberta Carbon Trunk Line, and the Alberta Carbon Conversion Technology Centre.
- Alberta's extensive experience with enhanced oil/gas recovery and acid gas injection are a strong foundation upon which to expand productive uses of captured CO_2.
- The expected growth of Alberta's clean hydrogen production capacity depends on reliable and effective sequestration of the carbon molecules that must be separated from natural gas.
- ERA's prior investments in feasibility and FEED studies for point source carbon capture have supported a first wave of full-scale carbon capture projects, but have also underscored the need for next-generation capture technologies to reduce costs and increase applicability for diverse flue gas streams.
- The large volume of CCS projects proposed for Alberta has highlighted the need to ensure safety, reliability, and permanence of various CO_2 sequestration methods.
- Direct Air Capture (DAC) requires an improvement in energy use, cost, and cold weather suitability, while bioenergy with CCS (BECCS) also faces similar technology and economic challenges.
- Alberta's vast areas of forests, wetlands, grasslands, and farmland present significant opportunities for carbon management but are coming under scrutiny for the impacts of current land use practices.







15-25%
SHARE OF GO-FORWARD INVESTMENT

A ROADMAP TO WHAT?

- Alberta's industries have access to best-available solutions for point source carbon capture; the costs, energy use, and other impacts of CCS technologies are broadly understood and able to be incorporated into corporate emissions reduction strategies.
- Alberta is home to multiple world scale CCUS facilities, acting as a testbed for new solutions and exporting provincial knowhow and intellectual property globally. Carbon injection activities in Alberta are the safest and most reliable in the world, setting the standard for high-quality carbon sequestration.
- With the maturation of technologies such as DAC and BECCS, new markets relating to carbon dioxide removals emerge and provide a critical resource for drawdown of atmospheric GHGs.
- New innovations pertaining to engineered or natural carbon capture are developed or attracted to Alberta and support Alberta's efforts to cost-effectively reduce emissions across a broad range of sectors.
- New digital and sensing solutions enable accurate measurement and management of biogenic carbon in forests and soils; when paired with new technologies and practices, these solutions enable Alberta's agriculture and forestry sectors to become world leaders in carbon management, increasing their competitiveness and significantly driving down their net emissions while enhancing climate resilience.

TECHNOLOGY EXAMPLES

- Next generation solutions for point source carbon capture, including pre-combustion, post-combustion, and chemical looping technologies.
- Application of CCS technologies to the bioenergy, electricity, waste-to-energy, and hydrogen sectors to deliver low- or negative-emissions energy products.
- Carbon dioxide removal technologies including direct air capture, BECCS, and nature-based solutions.
- Carbon utilization and conversion into value-added products.
- Measurement, management, and enhancement of natural carbon sinks such as soil and forest carbon, including improved land and forest management.

DELIVERING COMPLETE SOLUTIONS

ERA focuses on investing in late-stage, pre-commercialization technologies that reduce emissions and grow Alberta's economy, yet this approach is not sufficient to reach Alberta's environmental and economic goals. Reaching Alberta's potential within the outlined technology focus areas requires strategic initiatives such as sharing results and convening the right audiences to maximize investment impact and accelerate technology commercialization.

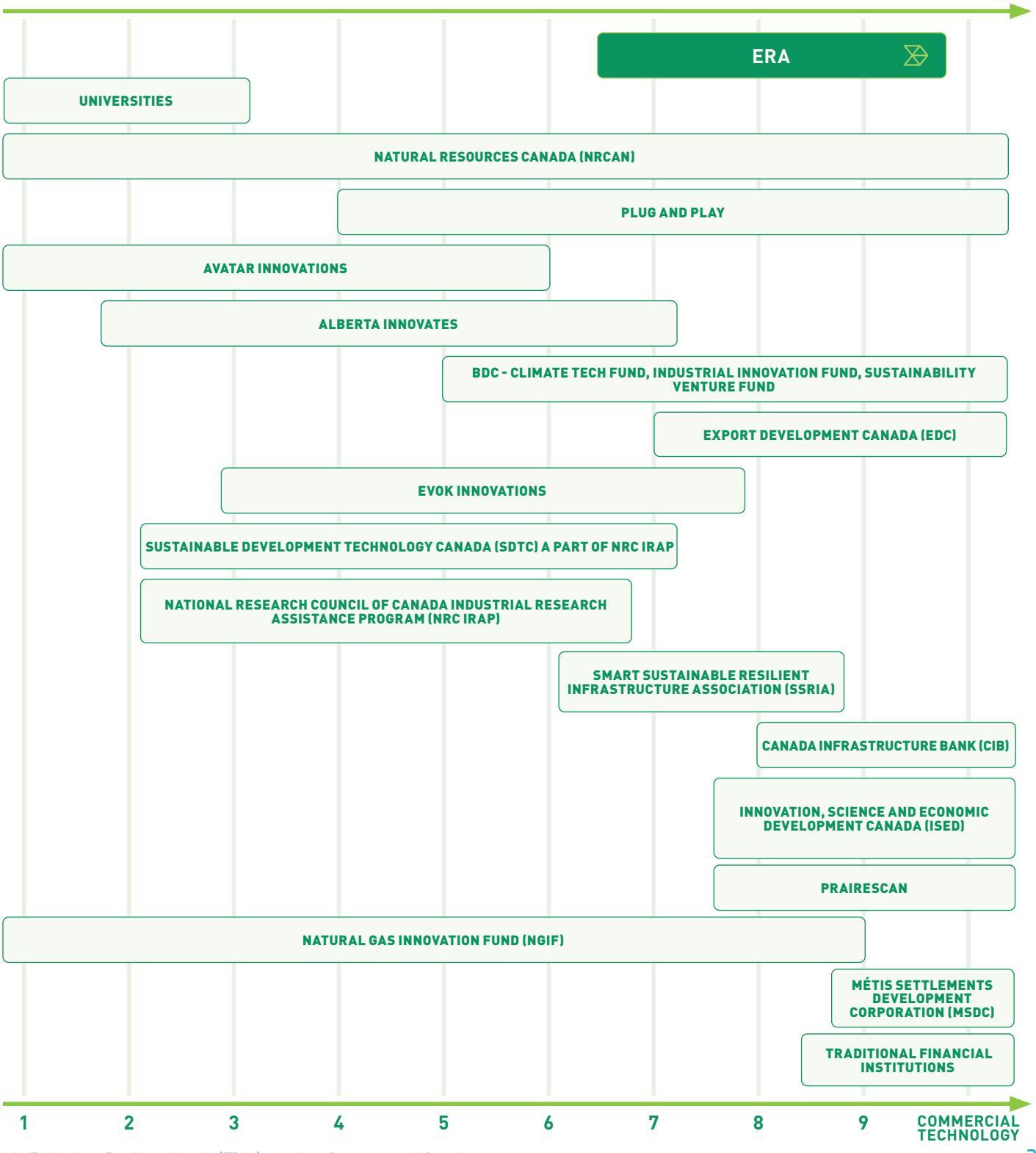
Here are some of the ways ERA achieves this objective:

- **Act as a convener.** Each technology focus area is led by a team of experts and visionaries who are working together to advance these solutions. ERA sits in a unique position with a lens across Alberta's entire emissions reduction innovation landscape. Bringing together these experts through roundtables, networking forums, and Lessons Learned events helps address timely topics to accelerate the success of ERA-funded technologies. Acting as a convener also allows technology innovators greater exposure to possible funding streams and access to later-stage funding opportunities beyond ERA's scope.
- **Serve as a thought leader.** Over time, ERA observes trends across its portfolio and within the technology focus areas and shares them with the rest of the innovation ecosystem. These trends are validated to inform future investments in emissions reduction.
- **Inform policymakers and regulators.** ERA funds innovative technologies that often push the boundaries of current commercial practices. The results of these projects can inform policymakers and regulators on how to best adapt to the changing technology landscape.
- **Tell Alberta's story.** ERA works with innovators to write articles, develop videos, and interview experts on its monthly podcast, Carbon Copy, to dive deep into the innovation opportunities and challenges that are supported through TIER funding. ERA routinely publishes project reports on its website and maintains a database of project information on its Open Data Portal. Storytelling around how ERA's past 15 years of investments demonstrates responsible stewardship of TIER funds.
- **Shape the future.** While most of ERA's work focuses on technology investment, there is a role to play in educating the next generation. ERA works with secondary and post-secondary institutions across the province to provide opportunities for students to learn and participate in its work.

ALBERTA ECOSYSTEM ALIGNMENT

ERA works to develop and enhance collaborative partnerships that help advance critical emissions-reducing technologies. The objective of a well-connected ecosystem ensures that ERA can leverage ecosystem partners' expertise and experience to more fully support innovators and gain a broader knowledge of high-potential technologies as they progress toward the demonstration and scale-up stages. This diagram provides a snapshot of the Alberta ecosystem.

TECHNOLOGY READINESS LEVEL[13]



13 Technology Readiness Levels (TRLs) overview. Government of Canada.

MEASURING PERFORMANCE

The TRM lays out a path for ERA to measure progress within each of the technology focus areas. The vision proposed within each area (i.e. A Roadmap to What?) helps align key environmental, economic, and social metrics against project outcomes, ensuring ERA selects projects for funding that align with its mandate and overall objectives as an organization. Establishing effective metrics to assess, track, and communicate the benefits of ERA's investment of TIER funds is an essential component of the ERA mandate.

There is inherent risk associated with investing in technology innovation and not all of the projects that ERA selects for funding are successfully completed. For example, a technology may not work as expected or may not be found to be economically feasible. In other cases, projects may not proceed due to financial or other factors. Targeting appropriate levels of attrition (i.e. project funding is awarded but not disbursed) and project success is a common facet of managing a portfolio of investments. Taking an appropriate level of risk when it comes to project success and attrition is key to ERA's success as a provider of patient capital to de-risk clean technology innovation.

ERA monitors project success across its portfolio and continues to understand the reasons why projects withdraw or do not conclude successfully. Tracking project performance across the portfolio enables ERA to calibrate its investment approach, ensure its project selection processes are delivering results, and address the reasons for project failure with the broader commercialization ecosystem. If the project failure is due to the technology itself, ERA uncovers why a technology may not have worked as planned and whether the market has found a different, more efficient solution. ERA is then able to revise its technology focus areas, learning from the challenges and barriers of that particular solution, and focus on technologies that continue to work towards meeting industry needs.

The Government of Alberta is ERA's key shareholder, and a key goal of the TRM is to demonstrate alignment with the strategic priorities of the province. Engaging with government staff and other stakeholders in the innovation ecosystem and sharing what is learned from the portfolio and how it evolves with time, remains a core part of measuring and reporting on performance. The TRM establishes a common framework and over-arching objectives for ERA's work, and it informs ERA's program planning (future-looking) and outcomes reporting (backward-looking) to government and other stakeholders. ERA's key strategic communications and reporting documents are the Annual Report, Stewardship Report (quarterly) and Business Plan. The annual three-year Business Plan builds on and operationalizes the TRM by focusing the strategy on specific programs, actions, and deliverables that ERA will take. Similarly, the Annual Report focuses on the delivery of the Business Plan, progress toward TRM focus area outcomes, and results from ERA's investments.

To support knowledge sharing that could further advance innovation, each project that ERA funds must submit a project completion report that outlines key outcomes and details the unique learnings. To ensure continued transparency, these reports are shared widely and available for public review.

In 2024, ERA launched an open data initiative designed to make investment information from technology projects easier to access. The new portal improves the experience by using dashboards to visualize ERA's portfolio of investments, allowing users to download a file directly from the website. Users can search by sector, primary technology areas, stage of innovation and type of organization.

SUMMARY

ERA's TRM serves as an important tool in steering the organization's technology investments toward achieving meaningful emissions reductions and economic growth in Alberta. By aligning its efforts with the Government of Alberta's objectives, the TRM ensures that ERA's investments are strategically targeted to best support the province's overall goals. This Roadmap identifies key opportunity areas for transformative intervention and reflects a commitment to adapting and evolving in response to global technological disruptions and market changes.

The TRM highlights ERA's dedication to balancing immediate and long-term needs. Its guiding principles emphasize leveraging Alberta's unique strengths, focusing on current and emerging technology trends, and adopting a balanced portfolio approach to managing risks and rewards. This edition of the TRM will be successful not just by effectively guiding ERA's future investments into the technology solutions Alberta and the world need, but also by inspiring a shared conversation and renewed vision for the benefits that innovation can bring.

Through ongoing consultation with stakeholders and a keen focus on both technology innovation and ecosystem alignment, ERA aims to drive meaningful progress towards carbon neutrality while enhancing the competitiveness of Alberta's industries. As ERA looks towards future roadmaps, its commitment to supporting Alberta's path to carbon neutrality remains firmly rooted in its mandate, harnessing both local and global technologies and solutions to achieve these ambitious goals.

For questions or comments about our Technology Roadmap, please reach out to info@eralberta.ca.

Photo: Calgary Aggregate Recycling. Soil Reuse Facility Expansion.

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