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# Alberta Hydrogen Roadmap

## Executive Summary







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# Introduction

Hydrogen is the most abundant element in the universe. It is a versatile energy carrier that is expected to play an important role in the lower carbon energy future because when combusted, hydrogen produces no greenhouse gas (GHG) emissions.

The global hydrogen economy is gaining momentum. During the past few years, national hydrogen strategies are emerging and worldwide deployment and investments across the hydrogen value chain are accelerating. Countries around the world are taking swift action to deploy hydrogen domestically and secure supply from international markets.

Hydrogen could provide up to 24 per cent of global energy demand by 2050, growing to almost 700 million tonnes per year.<sup>1</sup> This represents an almost eight-fold increase from the current global consumption of 90 million tonnes in 2020.<sup>2</sup> Meeting this global demand requires more than US\$11 trillion of investment in production, storage, and transport infrastructure. The global sale of hydrogen could exceed US\$700 billion by 2050, with billions more spent on end-use equipment.<sup>3</sup> The growing global interest in the hydrogen economy is shown with over 200 large-scale hydrogen projects recently announced world-wide.<sup>4</sup>

Alberta is among the largest global manufacturers of hydrogen, and Canada's largest producer of hydrogen and hydrogen carriers, such as ammonia and methanol. With an abundant supply of low-cost natural gas feedstock, decades of experience in producing hydrogen, and suitable pore space to permanently sequester carbon dioxide emissions, Alberta is well positioned to participate in a global hydrogen economy.

In 2020, Alberta's Recovery Plan and Natural Gas Vision and Strategy articulated an ambition to incorporate hydrogen into Alberta's current energy portfolio. Clean hydrogen, which is hydrogen produced with minimal emissions, is set to become a major part of Alberta's integrated energy system, advancing critical environmental outcomes and unlocking significant economic value.

Alberta's Hydrogen Roadmap connects ambition to action to outcome. It is an action plan that integrates hydrogen with the province's existing energy system and propels Alberta into the global hydrogen economy. However, to be successful a number of gaps and challenges must be resolved. The hydrogen economy is nascent and requires a concerted effort on behalf of industries, governments, and consumers. For Alberta to become a major player in the global hydrogen economy, the province will be required to take bold steps – leverage core strengths, catalyze technology development, and orchestrate the pathway to self-sufficiency and growth.

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<sup>1</sup> Bloomberg NEF, "Hydrogen Economy Outlook," March 30, 2020. <https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf>.

<sup>2</sup> International Energy Agency, "Global Hydrogen Review 2021," October 2021. <https://www.iea.org/reports/global-hydrogen-review-2021>

<sup>3</sup> Bloomberg NEF, "Hydrogen Economy Outlook," March 30, 2020.

<sup>4</sup> Hydrogen Council, "Hydrogen Insights," February 2021. <https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021.pdf>.

# Alberta's 2030 Hydrogen Ambition

In creating our provincial Hydrogen Roadmap, the Government of Alberta considered advice provided by industry, academia, municipalities, Indigenous organizations, third party research, and non-governmental organizations. Stakeholders advised of key requirements needed to enable a hydrogen economy in Alberta. These requirements informed the following seven policy pillars to achieve our ambition:

1. **Build New Market Demand.** Establishing hydrogen demand is needed to build out supply and commercialization pathways.
2. **Enable Carbon Capture, Utilization and Storage (CCUS).** For Alberta to deploy clean hydrogen into the economy, CCUS infrastructure must be widely available.
3. **De-risk Investment.** Long-term investment certainty and funding are required as hydrogen is an emerging opportunity with challenging economics.
4. **Activate Technology and Innovation.** Demonstration projects, research, and innovation are needed to prove and scale up emerging clean hydrogen technologies. Training and development with Alberta's world-class universities and technical schools are important to support a labour force capable of working within the hydrogen economy.
5. **Ensure Regulatory Efficiency, Codes, and Standards to Drive Safety.** As the clean hydrogen economy is emerging, a regulatory regime including codes and standards must be inclusive of hydrogen and enshrine a safety-first mindset across the value chain.
6. **Lead the Way and Build Alliances.** Public-private partnerships and government-to-government relationships, including with Indigenous governments, are essential to advance the hydrogen economy, send coordinated signals to investors, and build public education and acceptance.
7. **Pursue Hydrogen Exports.** The international community is looking to lock in hydrogen supply agreements now. Alberta must move aggressively to establish market access and close intra-Alberta and hydrogen export gaps in supply chain logistics.



## Ambition for 2030

Clean hydrogen is integrated at-scale into Alberta's domestic energy system for use in transportation, heat, power generation and renewable energy storage, as well as industrial use. Alberta has established itself as the global supplier-of-choice in clean hydrogen exports.

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# Alberta's Hydrogen Advantage

## Experience and scale

Alberta has been producing hydrogen for more than 50 years using natural gas as a production feedstock, and produces more than 2.4 million tonnes of hydrogen annually as part of current upgrading, refining, and petrochemical processes. As a result, Alberta's energy industry has developed significant expertise in producing, handling, and safely using hydrogen at the industrial scale. In the clean hydrogen economy, Alberta's ambition is to reduce the carbon intensity for existing industrial hydrogen production as well as create demand markets for heating, transportation, power generation and storage, and export.



### Clean Hydrogen Production in Alberta

Clean hydrogen is already produced in Alberta with projects that capture emissions from hydrogen production, such as at the Scotford Complex, Nutrien's Redwater Fertilizer Facility, and the North West Redwater Partnership's Sturgeon Refinery. The Alberta Carbon Trunk Line, the world's largest CCUS system with carbon dioxide (CO<sub>2</sub>) gathering and transportation infrastructure, is another example of critical infrastructure in our clean hydrogen economy.

Recently, there have been several proposals to construct new clean hydrogen production facilities in Alberta:

- Air Products announced plans to construct a new clean hydrogen energy complex in Edmonton, which includes the first hydrogen liquefaction facility in Western Canada.
- Suncor and ATCO are collaborating on early-stage planning for a clean hydrogen production facility near Fort Saskatchewan.
- Japan's ITOCHU Corporation announced a partnership with a Canadian subsidiary of Petronas to explore and plan for a natural gas-based ammonia facility with CCUS in Alberta to export ammonia as a hydrogen carrier to Asian markets.

## Competitiveness

Alberta has a distinct competitive advantage in place to lead Canada’s clean hydrogen economy. By leveraging Alberta’s competitive and business advantages, Alberta has the opportunity to expand into several clean hydrogen value chains and attract investment into Alberta as one of the lowest-cost producers of clean hydrogen in the world. Figure 1 below shows that hydrogen production costs in Alberta are competitive compared to other global jurisdictions such as the United States and Europe, when hydrogen is derived from natural gas coupled with CCUS.<sup>5,6</sup>

**FIG. 1: 2020 GLOBAL HYDROGEN PRODUCTION COSTS**

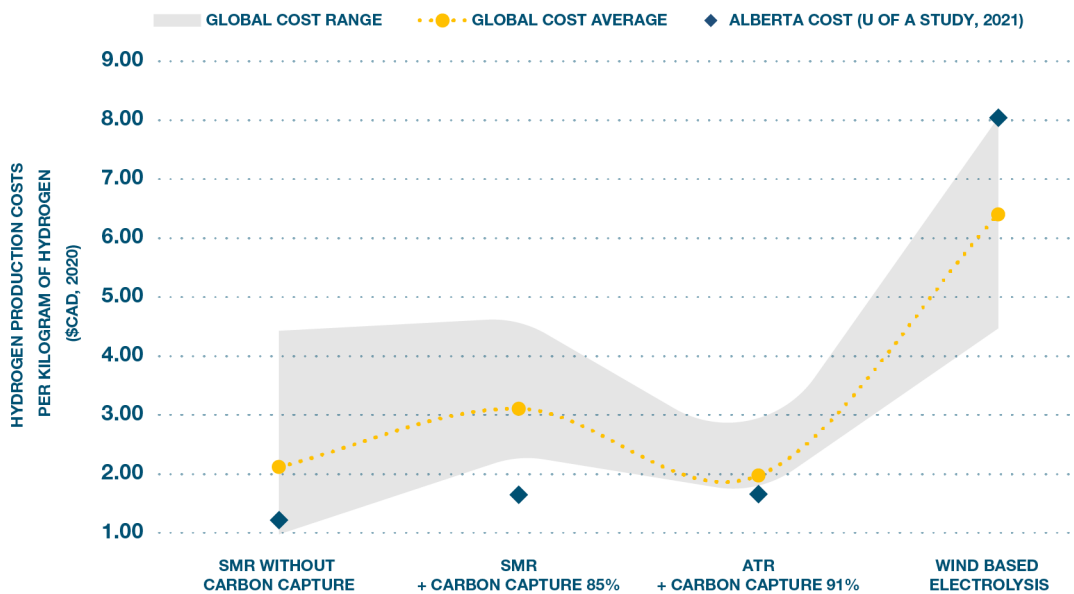


Figure 1. Alberta’s hydrogen production costs against global averages. Hydrogen production costs vary depending on facility size, type, feedstock, and energy use.

<sup>5</sup> University of Alberta, "Identification and Assessment of Opportunities for Hydrogen in Alberta’s Low-Carbon Economy," June 2021. Unpublished report commissioned for Alberta Department of Energy, Natural Resources Canada, and British Consulate-General Calgary.

<sup>6</sup> Alberta hydrogen production costs are sourced from the University of Alberta Report (2021). Global hydrogen production cost ranges are sourced from IHS United States, US Department of Energy, International Agency Europe, and the Transition Accelerator. IHS United States, US Department of Energy, IEA Europe, and the Transition Accelerator.

**FIG. 2: ALBERTA'S CLEAN HYDROGEN ADVANTAGES**



Figure 2. Alberta's competitive and business advantages for a clean hydrogen economy.

Alberta has the key building blocks in place to create a clean hydrogen economy. Large-scale deployment of clean hydrogen presents new opportunities for economic diversification, while supporting global emissions reductions. Alberta has competitive advantages and offers compelling business advantages for project developers by offering established incentive programs and supporting cross-sector hydrogen partnerships. Alberta also has industrial clusters in place that support clean hydrogen production and use at scale in concentrated regions.



# Benefits to Alberta

## Economic Growth

The clean hydrogen economy has the potential to significantly grow Alberta's energy sectors, increase productivity, and create jobs. To estimate the growth potential, initial macroeconomic analysis was conducted, which considered a scenario where hydrogen is widely integrated into Alberta's economy by 2030.

If Alberta were to undergo a transformative scenario with wide scale adoption of a clean hydrogen economy by 2030, tens of thousands of jobs could be sustained and billions of dollars of economic activity could be attracted during the construction phase. Following the construction stage, thousands of jobs and hundreds of millions of dollars of economic activity could be sustained during the operations stage.

The transformative scenario would require approximately 0.7 billion cubic feet of new natural gas demand in Alberta, should hydrogen be integrated across Alberta into sectors such as power generation, residential and commercial heating, industrial processes, transportation, and for exports.

## Emissions Reductions

Adoption of clean hydrogen in Alberta has the potential to reduce GHG emissions. Modelling conducted for the Hydrogen Roadmap shows that under a 2030 scenario where hydrogen is widely integrated into Alberta's energy systems at a large scale, the province could reduce GHG emissions by 14 million tonnes per year. This represents a reduction of five per cent of Alberta's 2019 emissions.

The emissions reductions by 2030 represent a solid starting point. Between 2030 to 2050, clean hydrogen could contribute to greater GHG emissions reductions as hydrogen deployment gains momentum across the province.



### Clean hydrogen export potential

Establishing a hydrogen export market has tremendous potential for Alberta.

The 2030 transformative scenario would require approximately **0.7 billion cubic feet of new natural gas demand in Alberta**, should hydrogen be integrated across Alberta into sectors such as power generation, residential and commercial heating, industrial processes, transportation, and for exports.

A hydrogen market exporting **10 million tonnes of clean hydrogen per year** from Alberta to international markets by 2050 could demand about **4 billion cubic feet per day in natural gas**, supporting jobs and revenue in Alberta and global emissions reductions. This would grow Alberta's natural gas value chain, which is already one of the cleanest in the world with best-in-class environmental standards.

# Alberta's Clean Hydrogen Production Approach

Alberta can produce low-carbon hydrogen using natural gas-based technologies such as steam methane reforming and autothermal reforming with CCUS. Alberta also has renewable resources such as wind and solar to support electrolytic hydrogen, biomass-based hydrogen production, and emerging in-situ technologies.

Today, global jurisdictions are establishing carbon intensity thresholds to define clean hydrogen. The CertifHy project, which is Europe's first Guarantee of Origin for low-carbon hydrogen, identifies a carbon intensity threshold of approximately 4.37 kilograms of CO<sub>2</sub> per kilogram of hydrogen, including upstream emissions.

Analysis done for the Hydrogen Roadmap highlights how different hydrogen production methods in the province compare against this carbon intensity threshold (Figure 3). As global low-carbon thresholds are established, Alberta will collaborate with other governments and international partners to support the development of science-based carbon intensity thresholds for hydrogen production. This collaboration will be important to establish carbon intensity threshold targets, definitions, and measurement and reporting standards.

**FIG. 3: CARBON INTENSITY OF HYDROGEN PRODUCTION IN ALBERTA**

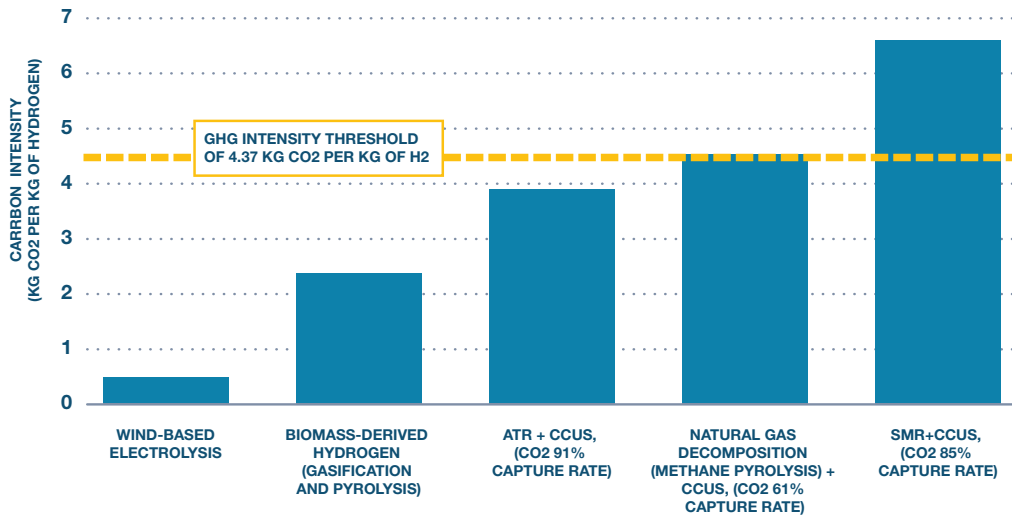
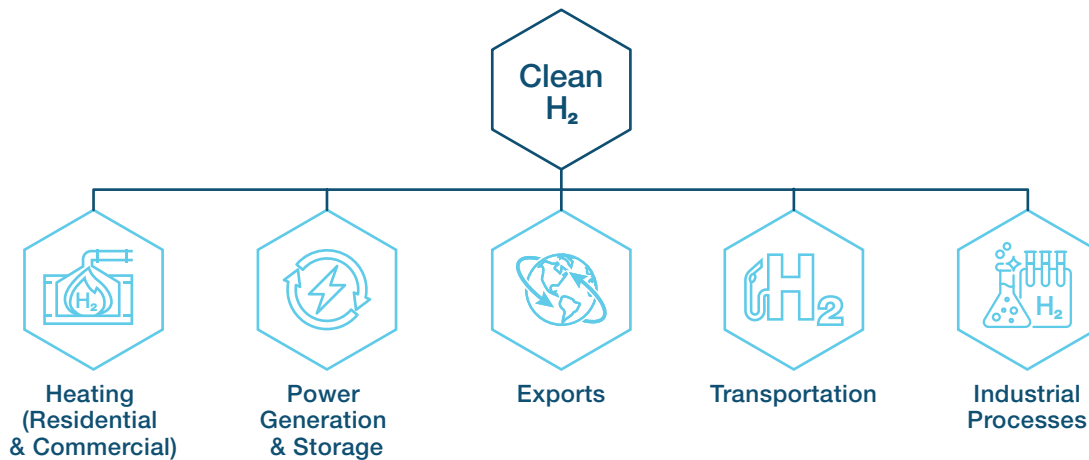


Figure 3. Comparison of carbon intensity by production technology in Alberta (2020). The carbon intensity data is sourced from the University of Alberta Report (2021) and includes upstream and hydrogen production emissions.

For electrolytic hydrogen production in Alberta, the source of grid power is important when assessing lifecycle emissions of different production pathways. Canada's Hydrogen Strategy indicates that lifecycle emissions of electrolytic hydrogen production based on the Alberta grid will be larger than lifecycle emissions from natural gas-based production pathways coupled with CCUS.

The carbon intensity of greenhouse gas emissions from hydrogen production is only one consideration when assessing the environmental benefits of energy systems. Other considerations include environmental impacts from land use changes, energy storage, water availability, biodiversity impacts, and public concerns. These additional social and environmental impacts should be assessed when deciding on hydrogen production pathways according to regional circumstances.

## Alberta's Hydrogen Markets



The Hydrogen Roadmap identifies four leading domestic markets for clean hydrogen, which include heating (residential and commercial), power generation and storage, transportation, and industrial processes. The roadmap also recognizes hydrogen exports as a significant economic opportunity for Alberta beyond its borders.

In evaluating the potential hydrogen economy, Alberta modelled two possible 2030 scenarios for the province:


- **An Incremental Future**, where clean hydrogen has slow uptake into the provincial economy. This scenario assumes incremental (business-as-usual) hydrogen demand based on existing policy and regulations, with some initial momentum from industry, incremental progress on technology, and less optimistic growth rates.
- **A Transformative Future**, where clean hydrogen is integrated into provincial energy systems on a larger scale. This scenario assumes a supportive policy environment that facilitates demand creation and technological development, favourable socio-economic conditions, and growth rates that will lead to large-scale domestic hydrogen deployment and exports by 2030.

## Domestic Markets

Integrating clean hydrogen into domestic end-uses provides opportunities to decarbonize the following markets and support investment attraction and retention.

### Residential and commercial heating

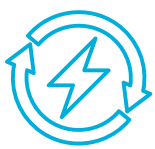
Over the next five to ten years, Alberta's focus will be on enabling hydrogen blending into natural gas distribution systems while piloting higher concentrations of hydrogen blending and pure hydrogen networks in contained areas such as isolated portions of the natural gas network. Clean hydrogen may play a significant role in residential and commercial heating, along with other alternatives that reduce emissions.

	Incremental future	Transformative future
	<p>Pilot projects are testing hydrogen blended at five per cent by volume with natural gas into municipal and/or rural residential, low-pressure distribution infrastructure.</p>	<p>Hydrogen blended at 15 per cent by volume is occurring in municipal and/or rural distribution infrastructure across the province. Pure hydrogen networks and communities are demonstrated for 200,000 residences, taking advantage of expected continued growth in the Alberta housing market.</p>

### Power generation and storage


Power generation facilities in Alberta continue to undergo coal-to-gas conversions, with the majority of coal-fired electricity being replaced by natural gas. This provides the opportunity for clean hydrogen to be integrated with natural gas as a fuel source and also support energy storage.

Hydrogen can serve as large-scale energy storage for intermittent renewables and can fuel hydrogen-capable turbines or stationary fuel cells. The future state of integrating hydrogen into the power generation and storage sector will ultimately depend on proving technology at the commercial scale and ensuring competitiveness. The transition toward a clean hydrogen economy will need to support market competition and affordability of power generation for end users.

	Incremental future	Transformative future
	<p>The power generation sector is largely business-as-usual with feasibility and demonstration projects in place. There is public-private partnership support for pilot projects that demonstrate hydrogen energy storage in underground salt caverns or depleted oil and gas reservoirs.</p>	<p>1200 MW of Alberta's power generation is using 15 per cent volume of blended clean hydrogen with natural gas in regional clusters. In addition, there is a power generation project demonstrating hydrogen powered turbines. Hydrogen is also used as a seasonal storage system from surplus renewable power through power-to-gas.</p>


## Transportation

Large captive vehicle fleets such as buses and commercial trucks are seen as having the highest potential for adoption in Alberta. Fuel cell electric vehicles (FCEVs) offer the greatest advantages over other low-emission alternatives in energy intensive, long-range applications such as heavy-duty trucking. Fleets with return-to-base operations can leverage shared infrastructure, reducing transition costs in the early deployment phase. The higher daily hydrogen usage per vehicle in heavy-duty applications also builds deployment scale and improved economics with a smaller number of vehicles.

	Incremental future	Transformative future
	One per cent of gasoline vehicles and five per cent of diesel vehicles have transitioned to FCEVs.	Five per cent of gasoline vehicles and 10 per cent of diesel vehicles have transitioned to FCEVs.

## Industrial processes

Upgrading current hydrogen production methods to include CCUS represents an early opportunity for clean hydrogen leadership in Alberta.

	Incremental future	Transformative future
	CCUS is added to existing hydrogen production at bitumen upgrading and/or oil refining sites to reduce emissions by 6 Mt per year.	CCUS is added to hydrogen production facilities at bitumen upgrading and/or oil refining sites, and CCUS is added to hydrogen production at ammonia and methanol facilities to reduce emissions by 12 Mt per year. A project for clean ammonia production is operating.

## Exports


Alberta's biggest economic opportunity in the hydrogen economy is export markets, preserving Alberta's wider market access for energy commodities and ensuring future energy competitiveness. In addition to domestic markets, Alberta has the resources to produce significant volumes of clean, cost-competitive hydrogen to meet global market demand.

Canada's Hydrogen Strategy estimates by 2050, the Canadian domestic market for hydrogen could be up to 20 million tonnes per year, and hydrogen export to meet international demand for clean hydrogen could more than double this amount.<sup>7</sup> Alberta's capacity for clean hydrogen production could be approximately 45 million tonnes per year, demonstrating that Alberta has the production capacity to satisfy local demand, while providing significant export quantities to other Canadian provinces and international markets.<sup>8</sup>

Potential target export markets include Canadian and North America jurisdictions, Europe, and Asia Pacific customers. To meet overseas demand for clean hydrogen, liquid hydrogen carrier ships are currently under development.

Hydrogen export by pipeline could use a dedicated gaseous hydrogen pipeline or blend hydrogen into existing natural gas pipeline networks. Existing high-pressure natural gas pipelines could also be converted to deliver pure hydrogen, however this must be evaluated and assessed as a suitable business case.

Another opportunity for Alberta, especially as global hydrogen export supply chains are emerging, is to export hydrogen in the form of ammonia. Exporting hydrogen in the form of ammonia is a cost-competitive opportunity for Alberta, especially if end-use sectors can directly use ammonia in their applications. Other hydrogen carriers, such as methanol or liquid organic hydrogen carriers, will be explored as Alberta evaluates its export opportunities.

	Incremental future	Transformative future
	Alberta is exporting clean hydrogen carriers (for example, ammonia) by rail to the United States. Alberta has a framework and plan in place, developed with other provincial and federal governments in Canada, to export clean hydrogen to global markets.	Alberta exports 1 million tonnes of gaseous hydrogen, noting this would require a fully permitted and constructed pipeline to the west coast, liquefaction, and export infrastructure. In addition, Alberta also exports 1 million tonnes of hydrogen carriers (such as ammonia) to global markets by 2030. <sup>9</sup>

By 2050, Alberta's hydrogen export market could grow to 10 million tonnes of clean hydrogen per year and would use 4 billion cubic feet per day in natural gas, supporting jobs and revenue in Alberta and global emissions reductions.

<sup>7</sup> Canada, "Canada Hydrogen Strategy: Seizing the Opportunities for Canada," December 2020. [https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan\\_Hydrogen-Strategy-Canada-na-en-v3.pdf](https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf).

<sup>8</sup> University of Alberta, "Identification and Assessment of Opportunities for Hydrogen in Alberta's Low-Carbon Economy," June 2021.

<sup>9</sup> On August 3, 2021, Japan's ITOCHU announced a partnership with Petronas to explore and plan for a natural gas-based ammonia facility with CCUS in Alberta, to export ammonia as a hydrogen carrier to Asian markets.

# Action Plan

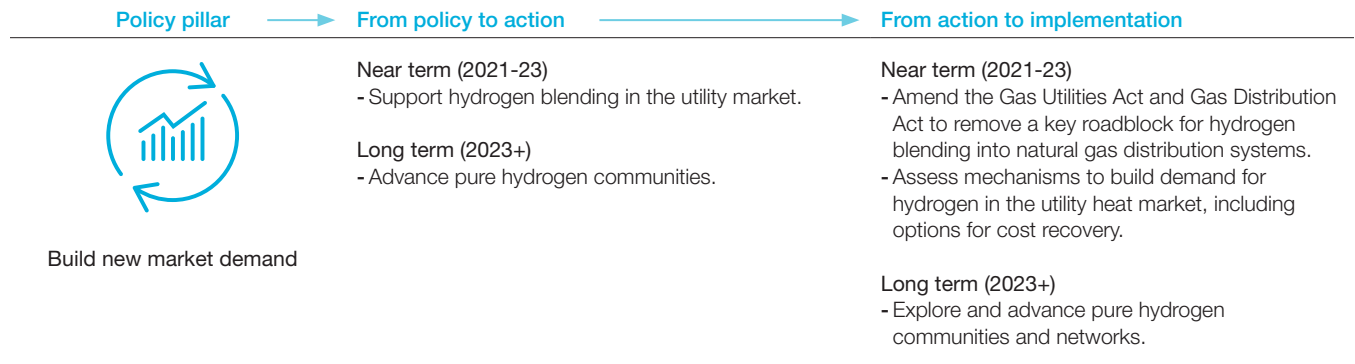
The Hydrogen Roadmap focuses on policy actions up to 2030 given the early stages of a clean hydrogen economy in Alberta. This focus will ensure that Alberta takes a measured approach in clean hydrogen development that drives gradual transition from pilot and demonstration stages to scale up, while playing a role in ensuring public safety and regulatory harmonization across the supply chain. These actions will be implemented by working closely with partner agencies, federal, provincial, and municipal governments, industry, and other key stakeholders.

## Policy actions

### 1. Build new market demand

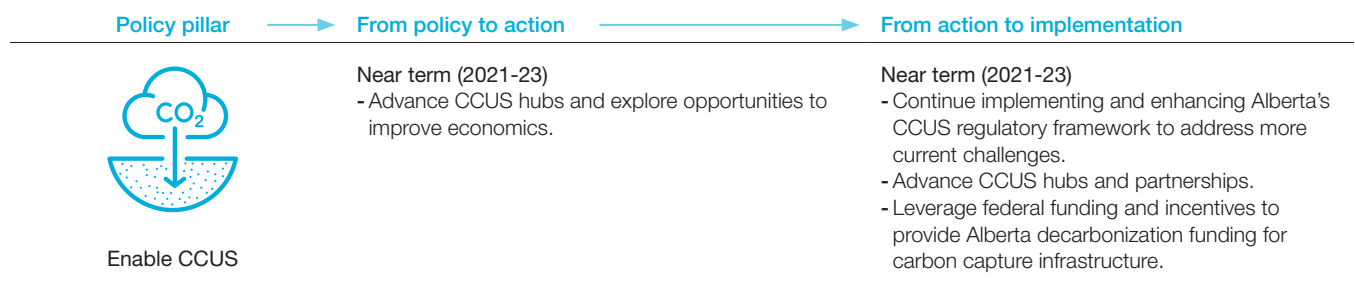
Alberta's current hydrogen economy is a balanced system where current hydrogen production meets demand for existing industrial processes. Establishing new hydrogen demand, outside of its traditional use as an industrial feedstock, will be critical to move into new markets.

Policy actions need to support emerging hydrogen markets, initially focusing on markets that provide opportunities to immediately deploy hydrogen into the provincial economy.



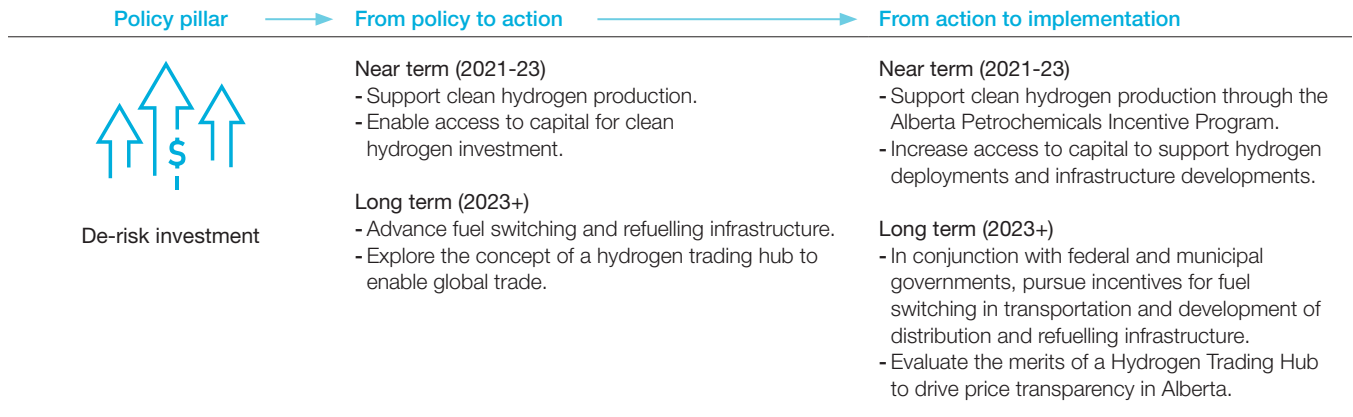
### 2. Enable CCUS

In order for Alberta to realize a clean hydrogen economy, CCUS needs to be in place to facilitate cost-effective, large-scale production. Although initial CCUS infrastructure is currently in place, the Government of Alberta is considering competitiveness and CCUS accessibility to various industries across the province.



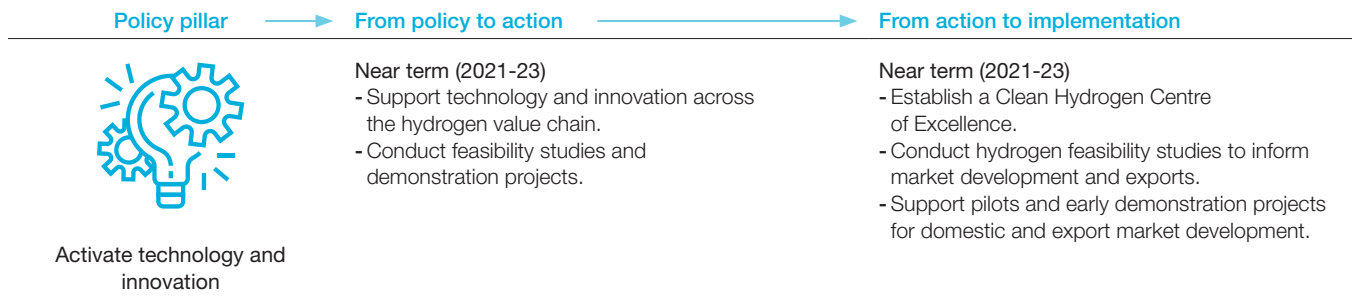
### 3. De-risk investment

Clean hydrogen is an emerging opportunity with challenging economics compared to conventional, higher-emission fuel sources. Long-term investment certainty and funding are needed to ensure investments can happen today to position Alberta for the long-term. Alberta's support to de-risk investment is focused on working in partnership with industry and other governments to enable new clean hydrogen production, improve access to capital, de-risk hydrogen use in transportation, and consider establishing a hydrogen trading hub.



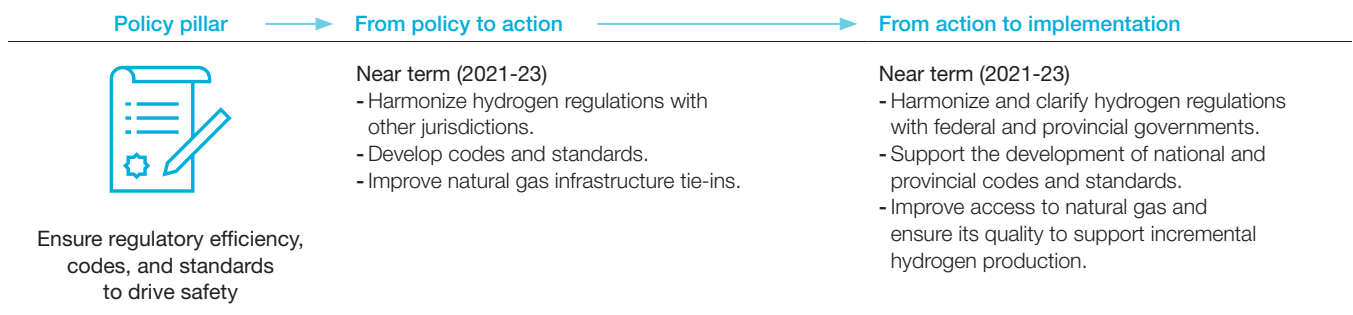
### 4. Activate technology and innovation

Demonstration projects, research, and innovation are needed to prove and scale up emerging clean hydrogen technologies. Training and development with Alberta's world-class universities and technical schools are important for the labour force to support the clean hydrogen economy.



### 5. Ensure regulatory efficiency, codes, and standards

Public safety must be prioritized by creating hydrogen codes and standards and regulatory requirements. A performance-based regulatory framework will allow hydrogen markets to move forward while reducing risk. Alignment of codes, standards, and regulatory harmonization with other jurisdictions is needed to ensure Alberta's competitiveness across the hydrogen economy.

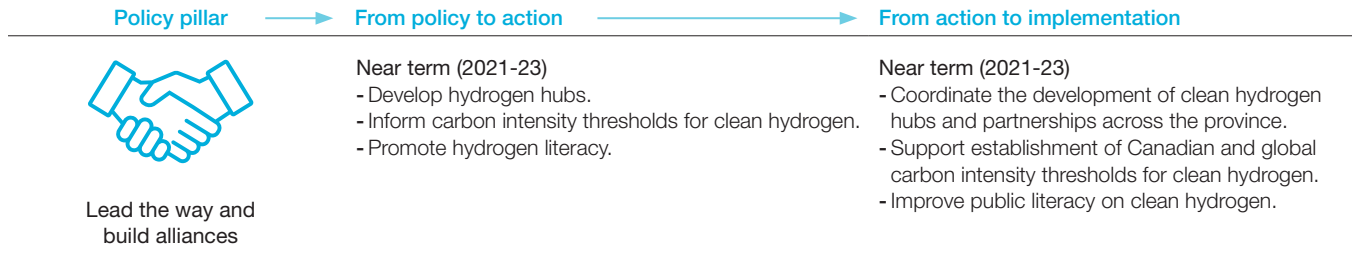




## 6. Lead the way and build alliances

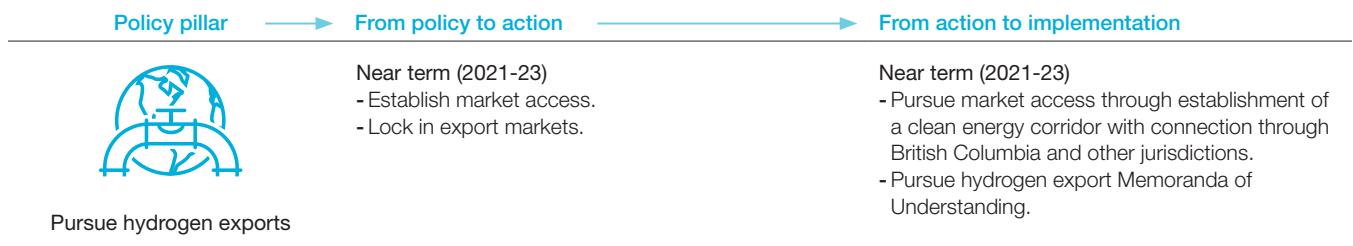
Public-private partnerships and government-to-government relationships, including with Indigenous governments, are essential to advance the hydrogen economy, send coordinated signals to investors, and build public awareness and understanding.

An emerging narrative against natural gas-based hydrogen production can disrupt Alberta's efforts to build a clean hydrogen economy. As Canadian and global carbon intensity benchmarks and Guarantee of Origin schemes are proposed and developed, Alberta needs to actively inform their development with data grounded in robust analysis and science.



## 7. Pursue hydrogen exports

Alberta has several advantages to supply global demand for clean hydrogen. However, Alberta needs to overcome operational constraints for export, such as an unavailable global supply chain, which includes infrastructure, transportation, liquefaction, and storage. Alberta will need to have an established export supply chain in place to benefit from the international export opportunity.



### Measures of success by 2030

To evaluate the success of the proposed policy actions, the Government of Alberta will use the following measures, as outlined under the 2030 Transformative Scenario:

- Domestic Hydrogen Deployment: Clean hydrogen is integrated into provincial energy systems (heating, power generation and storage, transportation, and industrial processes) on a large scale.
- Export: Alberta is exporting clean hydrogen (gaseous or as hydrogen carriers) to global markets.
- Investment: Over C\$30 billion in new capital investment is allocated to clean hydrogen production and development in Alberta, not including ammonia export.
- Economic Activity:
  - Tens of thousands of jobs and billions of dollars of economic activity during the construction phase.
  - Thousands of jobs and hundreds of millions of dollars of economic activity during the project operations phase.
- GHG Reductions: 14 Mt per year from integrating clean hydrogen into Alberta's markets, with most of the emissions reductions from industrial processes.



## Conclusion

Clean hydrogen has the potential to become a major part of Alberta's integrated energy system, decarbonizing hard to abate sectors and growing various segments of Alberta's economy.

The Hydrogen Roadmap focuses on policy actions up to 2030 given the early stages of a clean hydrogen economy in Alberta. This focus will ensure that Alberta takes a measured approach in clean hydrogen development that drives gradual transition from pilot and demonstration stages to scale up, while playing a role in ensuring public safety and regulatory harmonization across the supply chain.

In the first phase of implementing the Hydrogen Roadmap, the Government of Alberta will focus on establishing policy foundations, closing technology gaps and accelerating commercialization across the supply chain with dedicated research and innovation support, reducing carbon intensity of existing hydrogen production, and deploying clean hydrogen into the most promising end-use markets.

In the second phase of implementation, the focus will shift to growth and achieving scale through technology maturation and commercialization. During this phase, Alberta is expected to see a rapid evolution of its hydrogen value chain. Hydrogen deployment will increase as technologies move from concept to pilot and demonstration and eventually to wider hydrogen use and commercialization.

Once these actions are implemented, the Government of Alberta will closely monitor local and international developments in the hydrogen economy and will adjust the Hydrogen Roadmap as needed, treating it as a living document. The Hydrogen Roadmap will be revisited in 2025, to switch the focus to actions for the 2030-2050 timeframe and fully realize benefits to Albertans.