Enclosure 1

Overview of Hydrogen Technology

Presentation to Strathcona County
July 9, 2024

Emissions Reduction Alberta (ERA) and Transition Accelerator

About ERA

- **Mandate:** Reduce GHG emissions and grow Alberta's economy by accelerating the development and adoption of innovative technology solutions
- Supported by the Government of Alberta TIER fund
- Almost $1 billion invested to date across >250 innovation projects:
  - 1:1 private funds matching (nearly $9 billion total project value)
  - Competitive, two-stage, independent funding process
  - Approximately $100 million invested in hydrogen technologies to date

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The Transition Accelerator is a pan-Canadian organization that works with others to solve challenges through positive, transformational system change.

We're helping to ensure Canada builds a prosperous and economically competitive future by identifying and advancing viable pathways that lead to net-zero greenhouse gas emissions by 2050.

Agenda

- Overview – what is hydrogen?
- Hydrogen production
- Hydrogen distribution
- Hydrogen end-use
- Global context
- Questions

Overview: hydrogen's role in the energy system

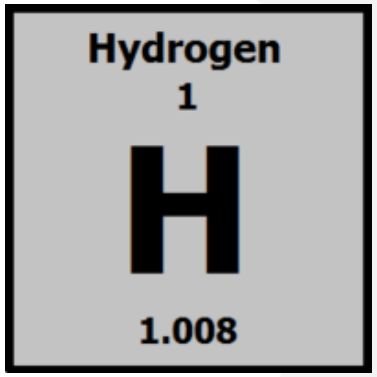
- Hydrogen is likely a necessary part of a net-zero energy system
  - Some regions <5%, some regions >20%—there is no consensus

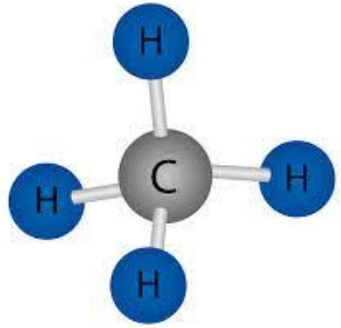
- Hydrogen is an energy carrier, not a primary energy source
  - Typically, must be made, and then converted into energy to be useful
  - Can occur in nature in the form of water or hydrocarbons

- Hydrogen is a gaseous fuel similar but different to natural gas
  - For some applications, hydrogen is a promising way to transition to net zero.

What is hydrogen?

- Most abundant element in the universe
- Almost always attached to other elements (i.e. water, hydrocarbons)
- Physical characteristics:
  - Gas at atmospheric conditions
  - High energy density by mass
  - Low energy density by volume
  - Colourless, odorless, non-toxic, combustible, explosive
  - Burns with a transparent flame
- Think of hydrogen as a fuel, similar to gasoline or diesel, but without the carbon

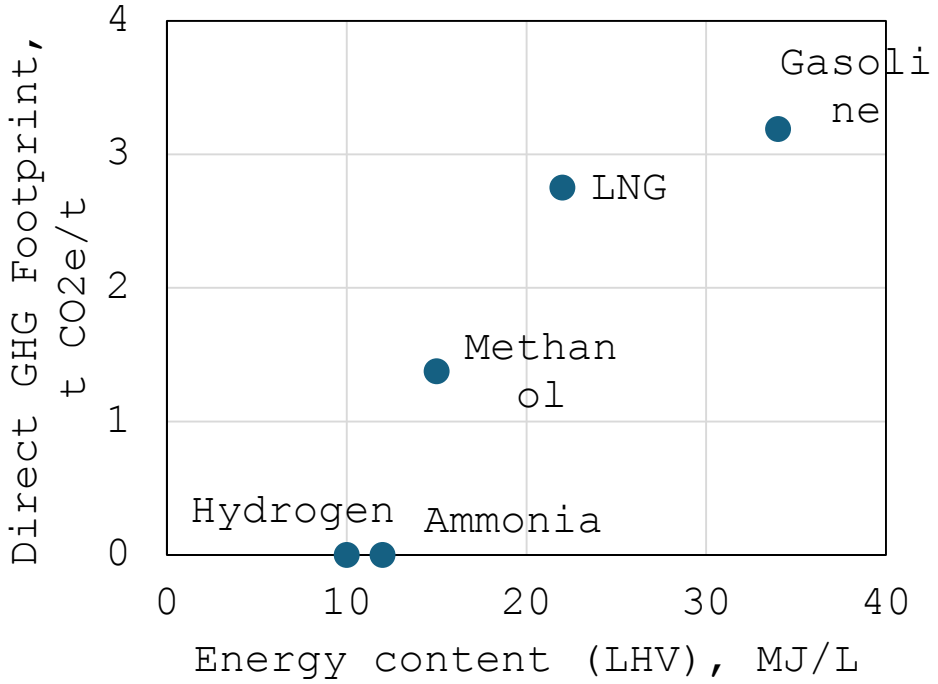




How is hydrogen used?

- Industrial chemical reactions:
  - Petrochemical production
  - Hydrocarbon refining
  - Fertilizer production
  - Steelmaking
- As a fuel to make energy:
  - Combustion
  - Converted to electricity via a fuel cell

Physical properties of hydrogen, carriers, and incumbents



Fuel type	Storage requirements
Gasoline	Liquid at atm
Natural gas	Liquid at -163 °C or gas at 200 bar
Hydrogen	Liquid at -252 °C or gas at 300 bar
Ammonia (NH_3)	Liquid at -33 °C
Methanol (CH_3OH)	Liquid at atm

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Hydrogen production

How is hydrogen produced?

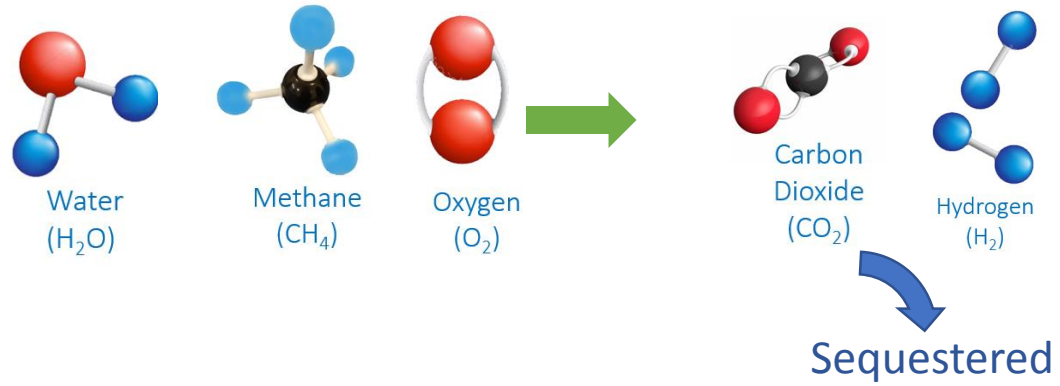
Most common methods

1. Methane reforming
2. Water Electrolysis

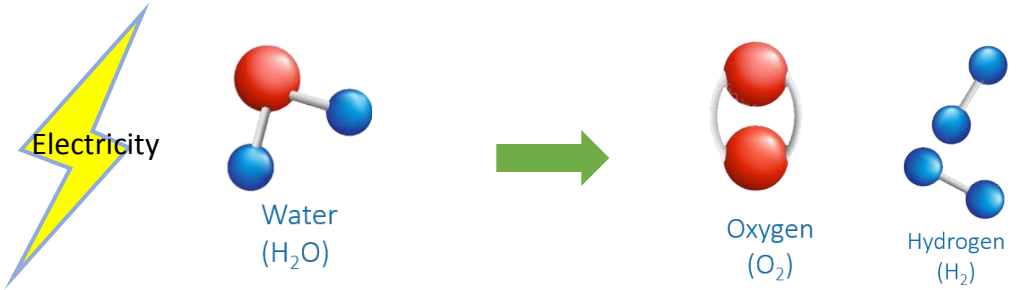
Other methods

- Chemical plant by-product
- Biomass gasification
- Methane pyrolysis

1. Methane reforming*

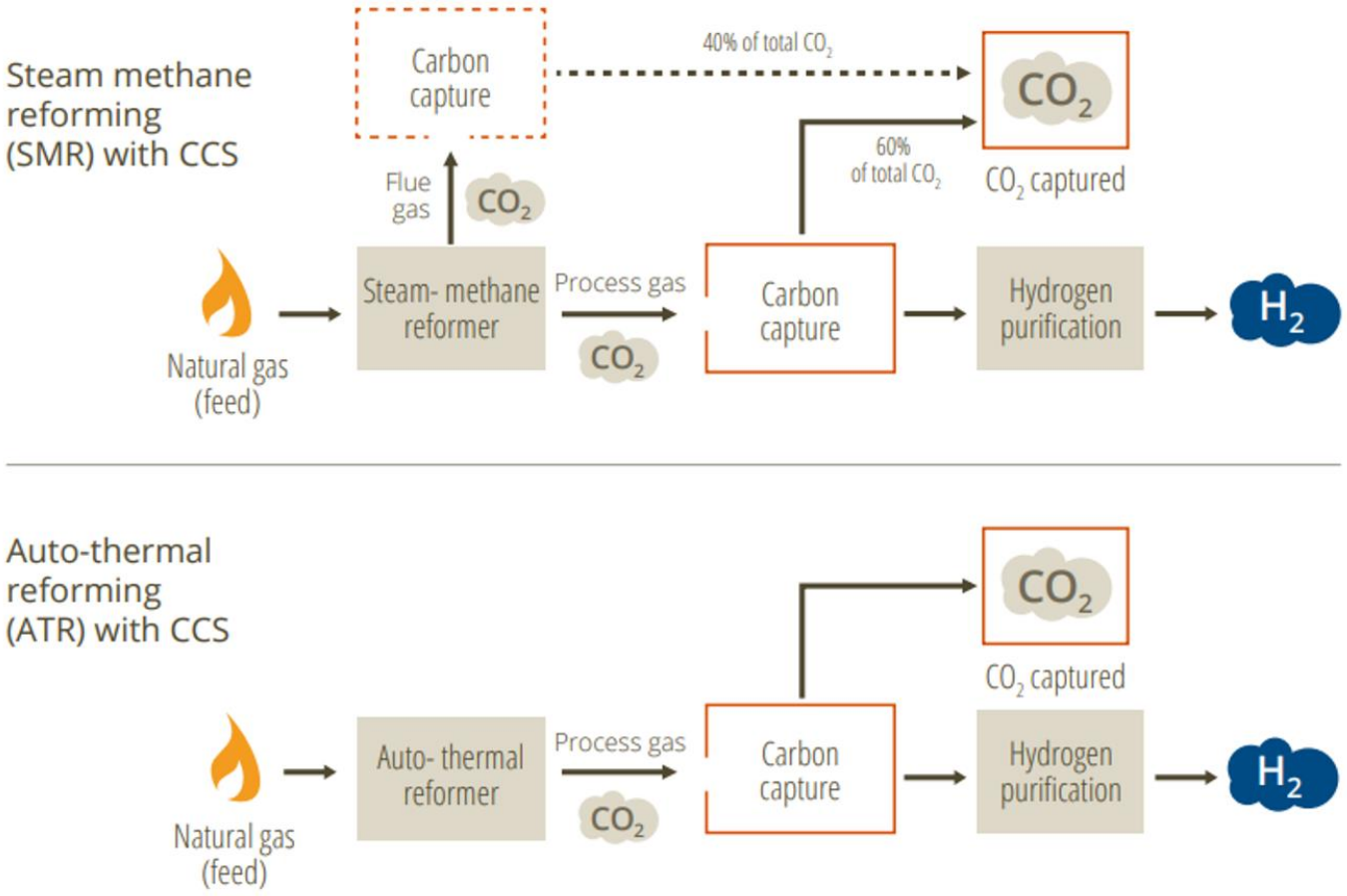


2. Water electrolysis



* There are multiple reforming methods at various Technology Readiness Levels, some involving more water, less water, no water, no oxygen, producing solid carbon instead of CO_2, etc.

Natural gas reforming



- **Inputs:** natural gas, heat, electricity, water
- **Outputs:** hydrogen, CO_2
- **SMR vs ATR:**
  - ATR is more electrically dependent
  - ATR is easier to capture CO2 from

Source: Pembina Institute

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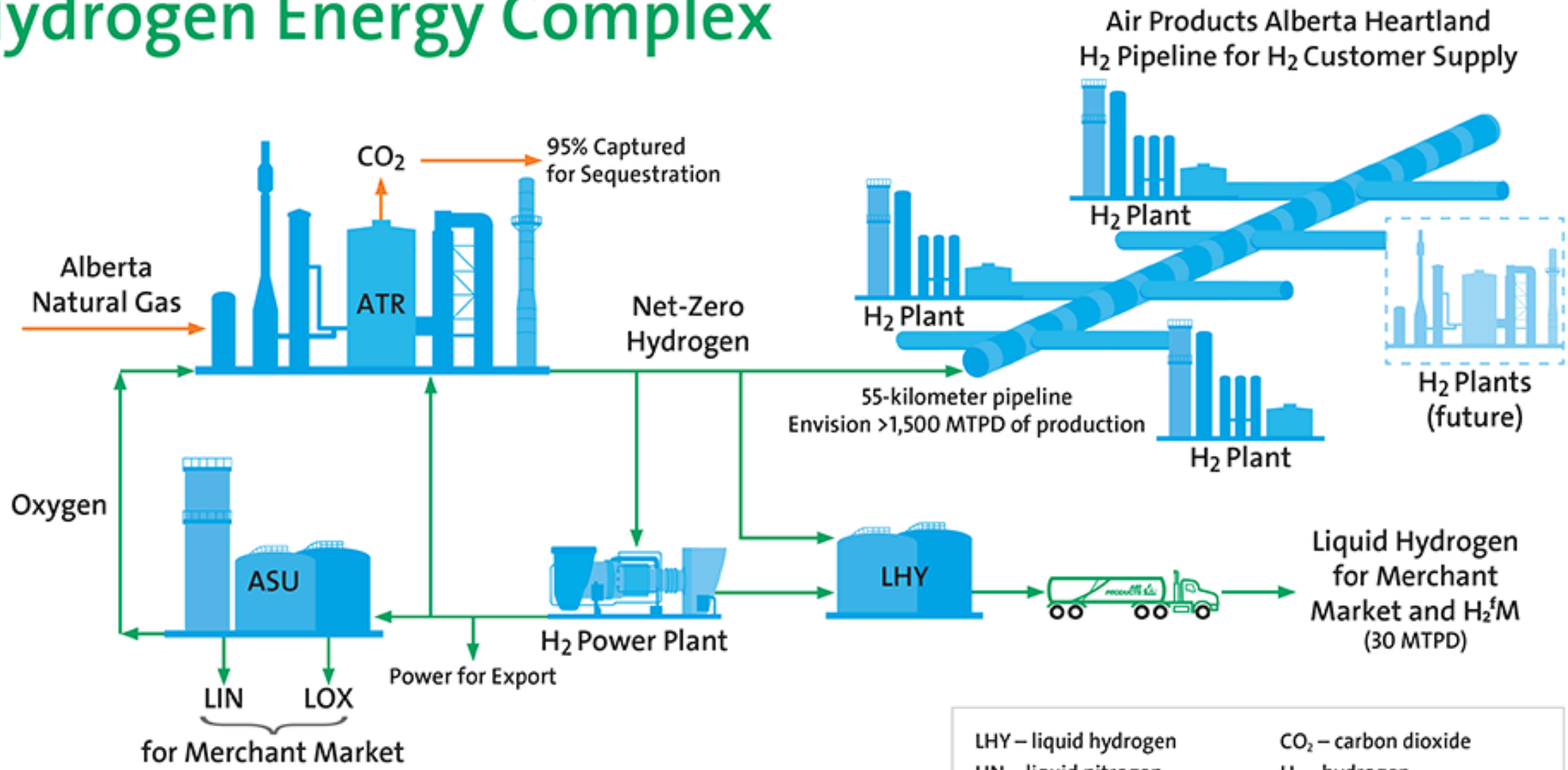
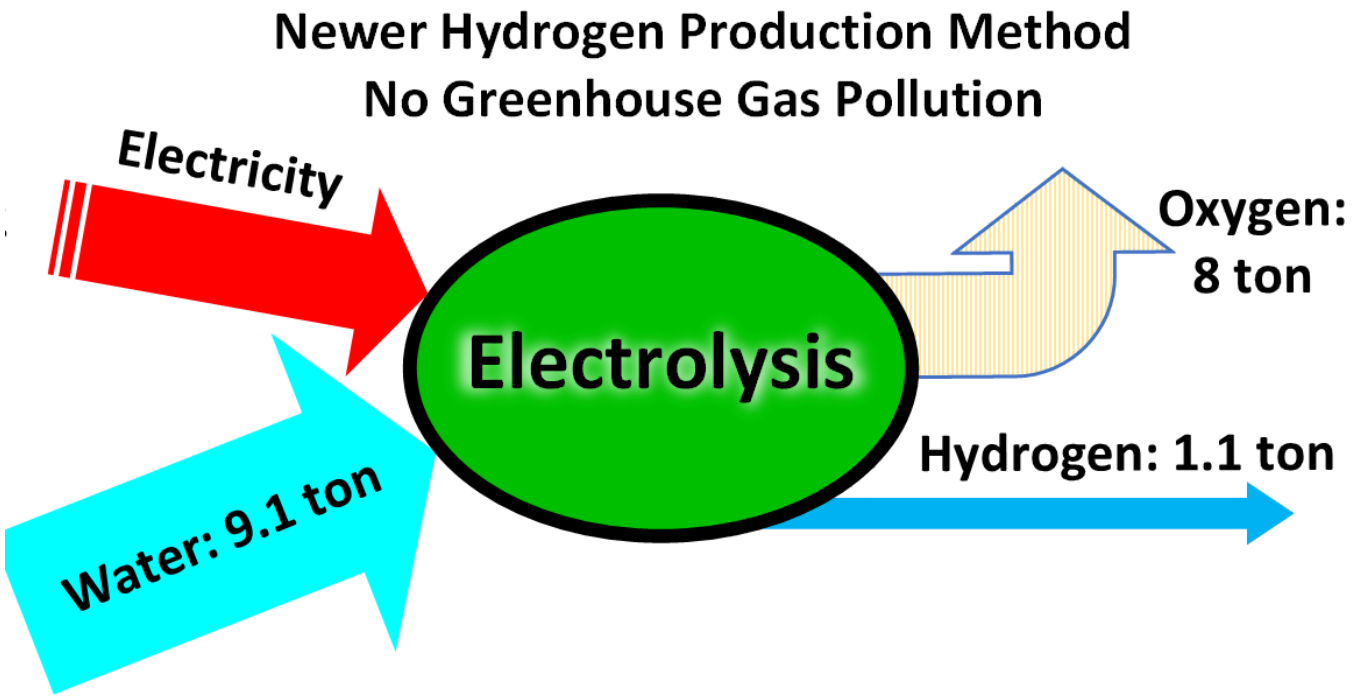
Shell Quest Project

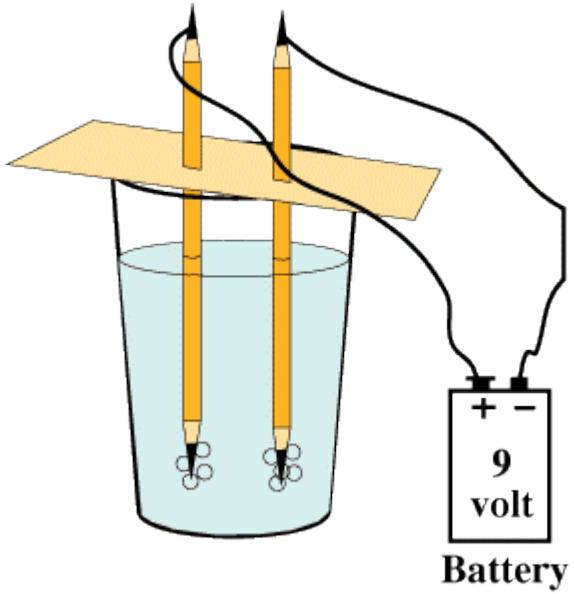
Air Products' World-Scale Net-Zero Hydrogen Energy Complex



Electrolysis



- **Inputs:** electricity, water
- **Outputs:** hydrogen, oxygen



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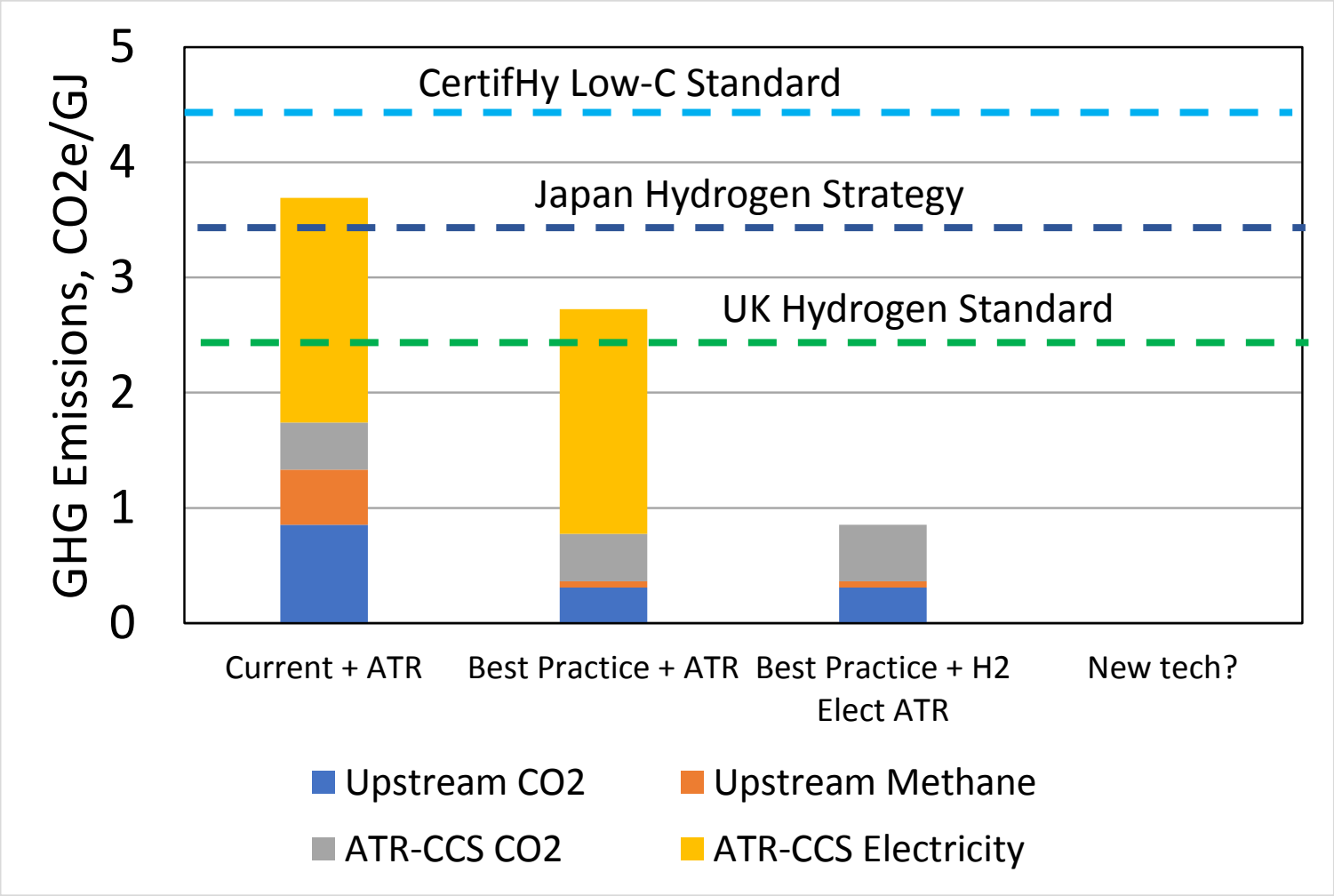
Lifecycle analysis of GHG intensity - example



- **ATR+CCS + average upstream natgas + grid electricity:** 3.7 $kgCO_2e/kg\ H_2$
- **+ best practice for upstream natgas:** 2.7 $kgCO_2e/kg\ H_2$
- **+ self-supply of H2 electricity to ATR facility:** 1 $kgCO_2e/kg\ H_2$

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Environmental impact of hydrogen production

Production method	Inputs	Outputs	Lifecycle emissions intensity	Water intensity
Electrolysis	Water + electricity	Hydrogen	Low-medium	High
Steam methane or auto-thermal reforming	Water, natural gas, and electricity	Hydrogen, CO2 emissions	Design dependant	Medium-high
Methane pyrolysis	Natural gas	Hydrogen, carbon black	Low-medium	Low

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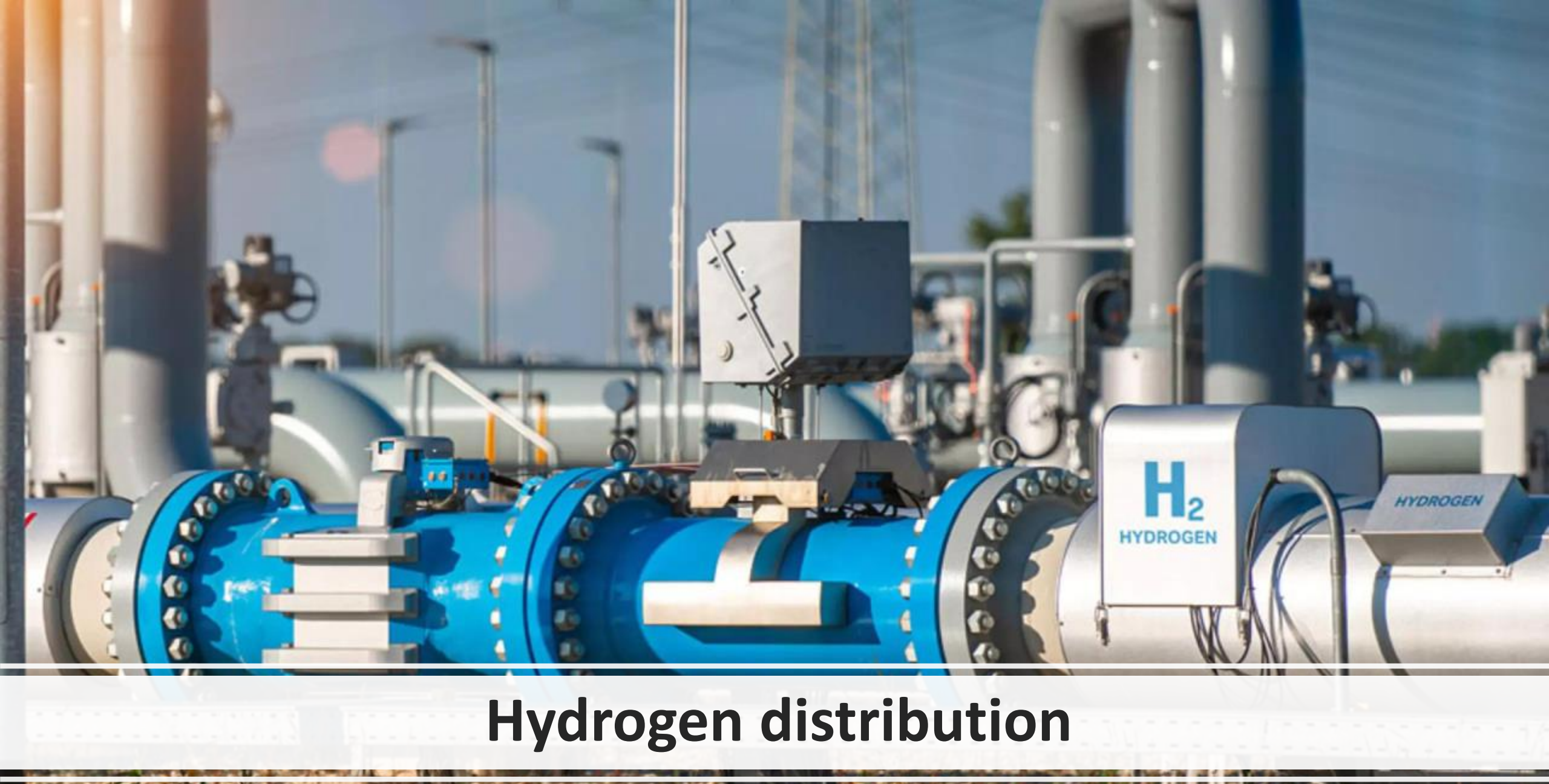
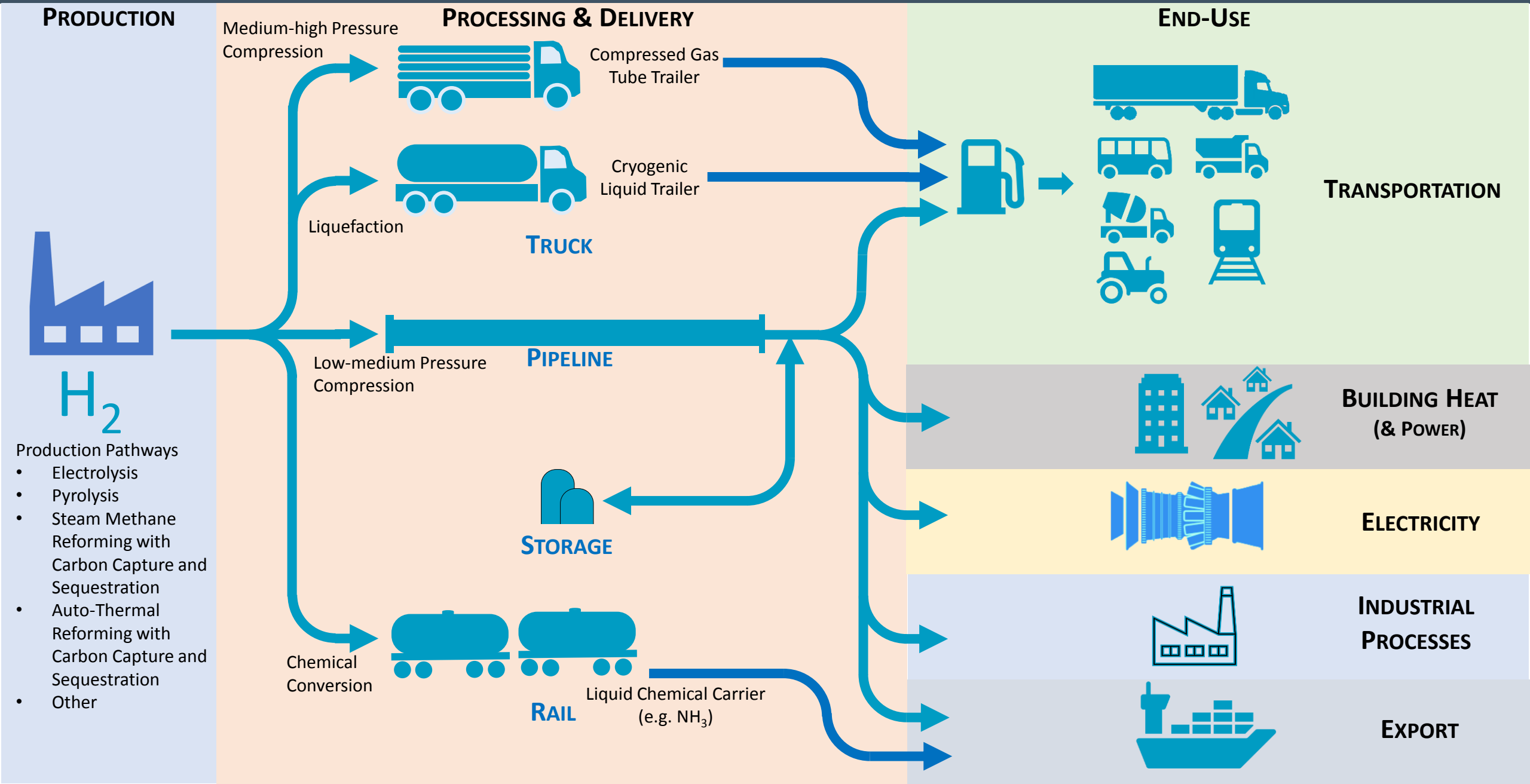
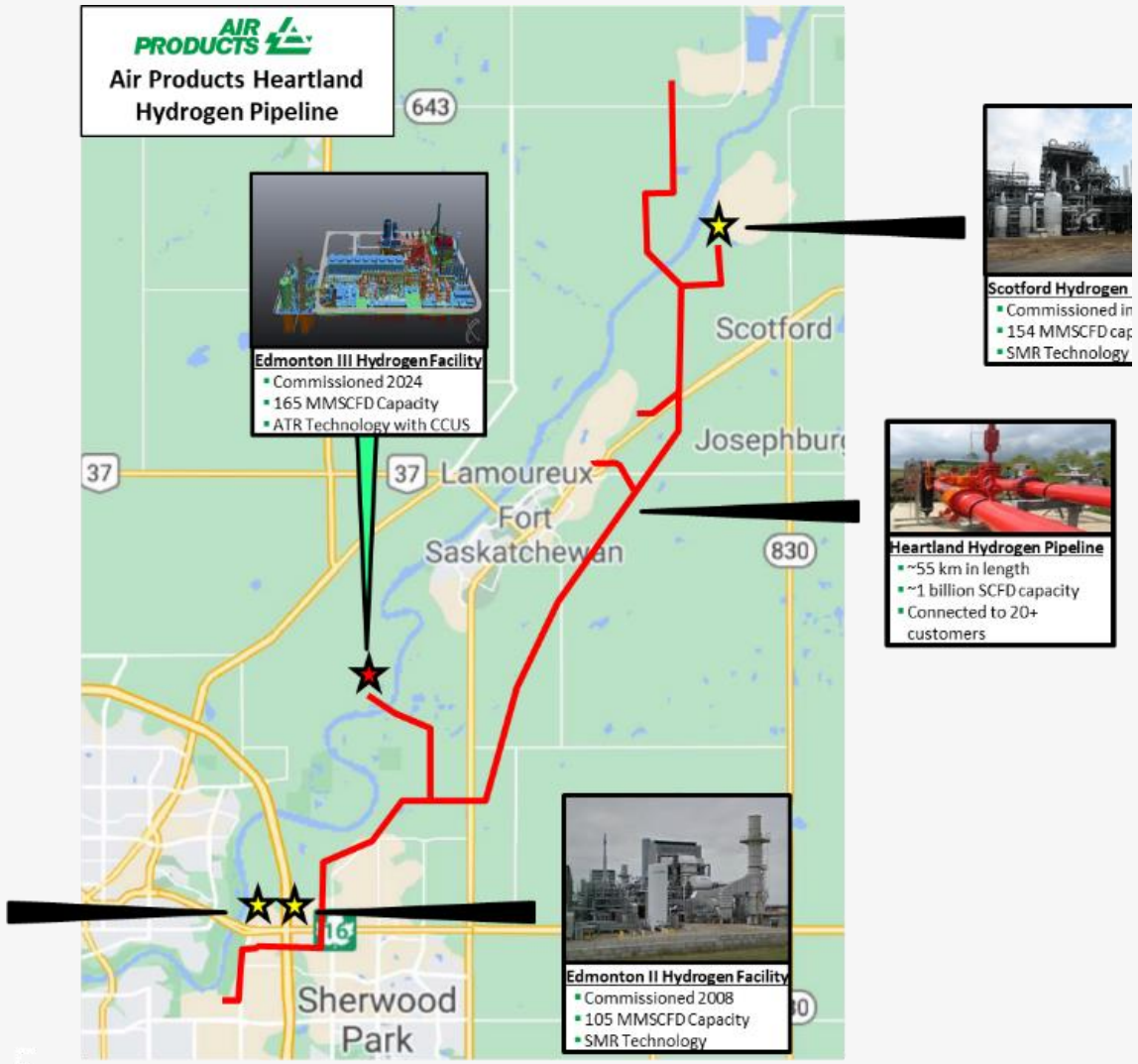


Hydrogen distribution

Towards a new H_2 value chain





Hydrogen in Alberta today

- Alberta is a major, low-cost producer of hydrogen, making 2.4 MT H_2 per year for $1-2 per kilogram
- Hydrogen is used currently in two main ways:
  - Key ingredient of ammonia used in fertilizer (NH_3)
  - Chemical for oil and gas refining/upgrading

Hydrogen distribution and storage

- Pipeline is by far the most economic way to transport hydrogen at scale
- Until pipelines are available, other methods may be used
  - Gaseous H2
  - Liquid H2
  - Liquid Organic Hydrogen Carriers (LOHC) e.g. Toluene
  - Other carriers, e.g. Methanol, Ammonia
- Will evolve as infrastructure develops
- Considerations
  - Costs
  - Purity
  - Safety and Regulations (utility vs merchant pipelines, mobile trailers, fueling stations)

Distribution options

Hydrogen blending

- Use legacy infrastructure
- Up to 20% (about 8% emissions reduction)
- Stimulate demand quickly

Pure hydrogen pipelines

- Need all new infrastructure
- Three to four times additional to compress, move compared to natural gas
- Need >1 tH_2 per day to be viable

Liquid hydrogen

- Energy intensive to liquefy
- Specialty cryogenic tanks
- Takes up three – five times more space compared to diesel

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Example: cost of delivered hydrogen

- Cost of production: $1-2 in Alberta (currently)
  - Lowest in the world
  - Producing hydrogen from natural gas, even with carbon capture, is much cheaper than other methods
  - Hydrogen is inherently more expensive to produce than natural gas
- Cost of delivered hydrogen:
  - In BC, subsidized to about $15per kgH2 at the pump (subsidized) → price competitive with gasoline on a per kilometer basis
  - Costs in Alberta for delivered hydrogen range $15-70 per kgH2+, depends on (1) method of production, (2) method of delivery, (3) distance of delivery, (4) scale…

Hydrogen end use

Converting hydrogen into useful energy

- Fuel cells
  - Combines H_2 and O_2 from the air in an electro-chemical reaction (like a battery) to produce electricity, some heat, and water
- Combustion
  - Burn H_2 with O_2 from the air to produce heat, water, and byproduct NOx

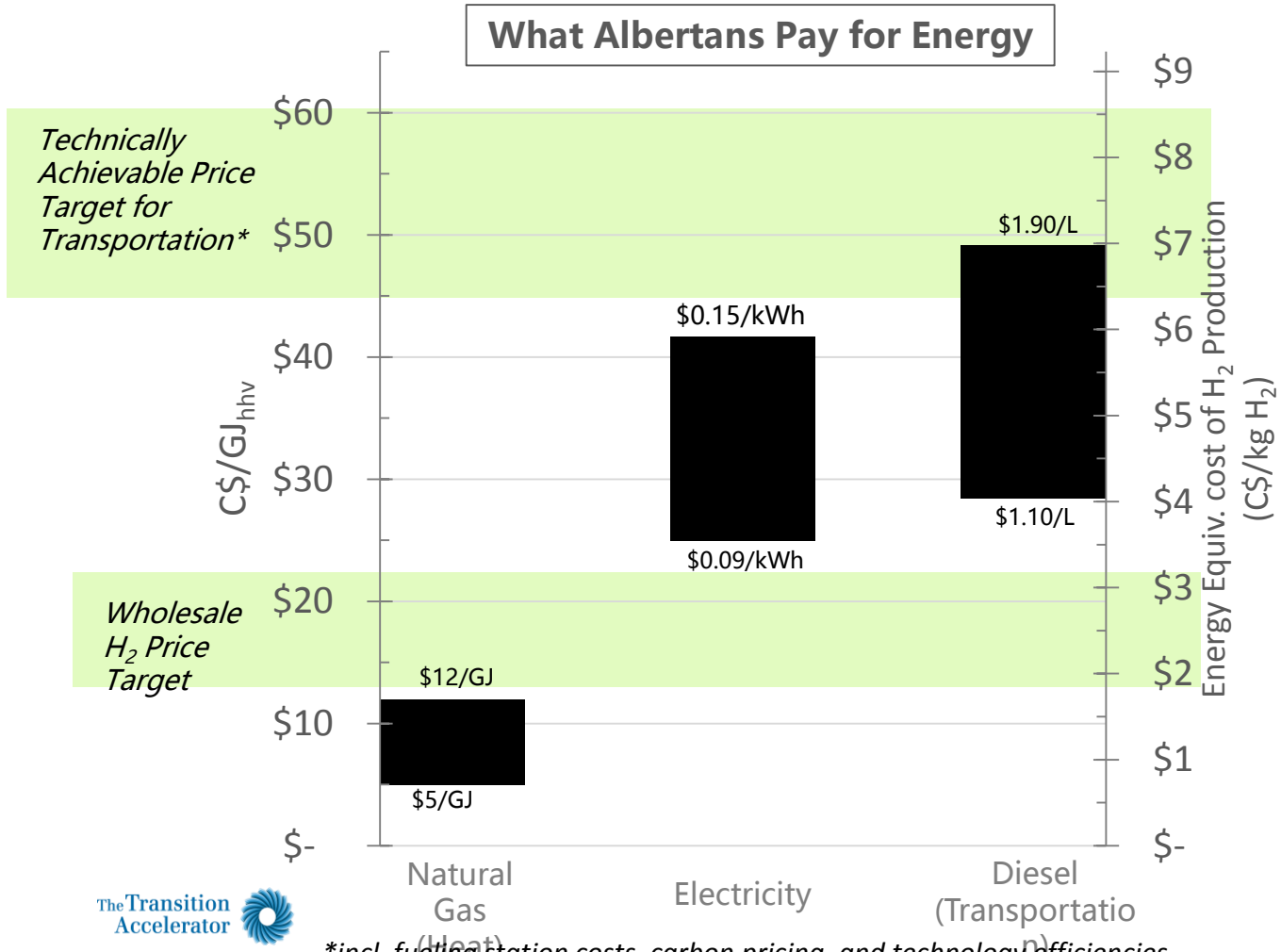
Fuel cell

Internal combustion engine

Images:
https://www.electronicdesign.com/markets/automotive/article/21155025/electronic-design-the-age-of-zero-emissions-heavy-duty-trucks-begins
https://www.nbmcw.com/equipment-machinery/construction-equipments/road-construction-equipment/200-000-hydrogen-engine-vehicles-to-be-sold-in-2035.html

Why start with hydrogen in transportation?

- Transportation has smallest gap between cost of hydrogen and fuel being replaced
- Transportation pilot projects can drive early demand for hydrogen at scale and unlock hydrogen for other sectors
- Need fueling infrastructure to build out transportation at scale



*incl. fueling station costs, carbon pricing, and technology efficiencies

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“Net zero” transportation options

- **Alternatives:**
  - Electric vehicles
  - Hydrogen fuel cell vehicles (also rely on an electric drive train)
  - Hydrogen combustion
  - Hydrogen dual fuel (co-combustion of diesel and hydrogen)
  - Biofuels – i.e. biodiesel, renewable natural gas
- **Applications:**
  - Trucks (everything from B-trains traveling cross country, to garbage trucks, etc.)
  - Transit buses
  - Trains (passenger and rail)
  - Passenger vehicles
  - Others (less relevant to Alberta): planes, shipping…

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Transportation pilots:

- CP Rail Hydrogen Locomotive Conversions
- Alberta Zero-Emissions Hydrogen Transit
- Diesel Tech Industries – Dual Fuel Trucking Retrofits

“Net zero” home heating options

- **Alternatives:**
  - Hydrogen
  - Biofuels
  - Electrification
- Pure hydrogen and/or electrification will ultimately require major infrastructure upgrades

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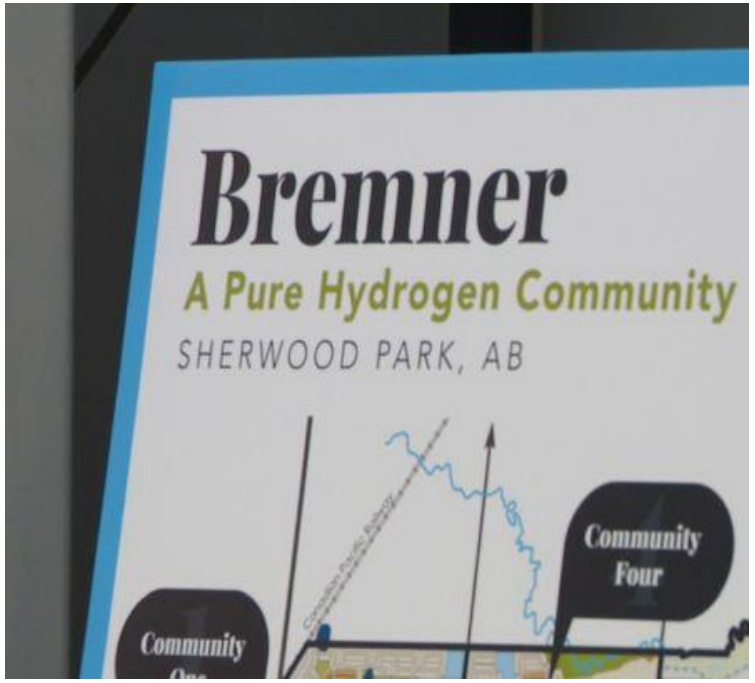

Heat and electricity pilots:

- ATCO Fort Saskatchewan Hydrogen Blending Pilot
- Millennium Place Combined Heat & Power Project
- Bremner Feasibility Assessment – 100% Hydrogen Community

Conclusion

- Strathcona County (and the general Edmonton region) have enormous advantages when it comes to hydrogen.
- The county is home to several world-leading, cutting-edge hydrogen pilot projects.
- These projects can de-risk broader deployment of hydrogen technologies in the county, Alberta, Canada, and the world!

Key resources

Recent ERA-Alberta Innovates hydrogen whitepapers:

- Research Reports - Emissions Reduction Alberta (eralberta.ca)
- **Alberta Low Carbon Hydrogen – How Low Can it Go?** and **Hydrogen Exports: Gap Analysis**

Other research reports:

- Alberta's Industrial Heartland Hydrogen Report
- Watersmart Regional Hydrogen Study

Other resources:

- https://cice.ca/knowledge-hub/the-potential-for-methane-pyrolysis-in-b-c-new-report-released/
- https://cice.ca/knowledge-hub/carbon-intensity-of-hydrogen-production-methods-report/
- https://transitionaccelerator.ca/reports/towards-net-zero-energy-systems-in-canada-a-key-role-for-hydrogen/
- https://transitionaccelerator.ca/reports/techno-economics-of-a-new-hydrogen-value-chain-supporting-heavy-duty-transport/
- https://www.alberta.ca/hydrogen-roadmap
- https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office
- https://www.pembina.org/reports/hydrogen-climate-primer-2020.pdf
- https://www.pembina.org/reports/carbon-intensity-of-blue-hydrogen-revised.pdf
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