NRC·CNRC

Clean Energy Innovation Research Centre

Advanced Hydrogen Production and Transport Technologies

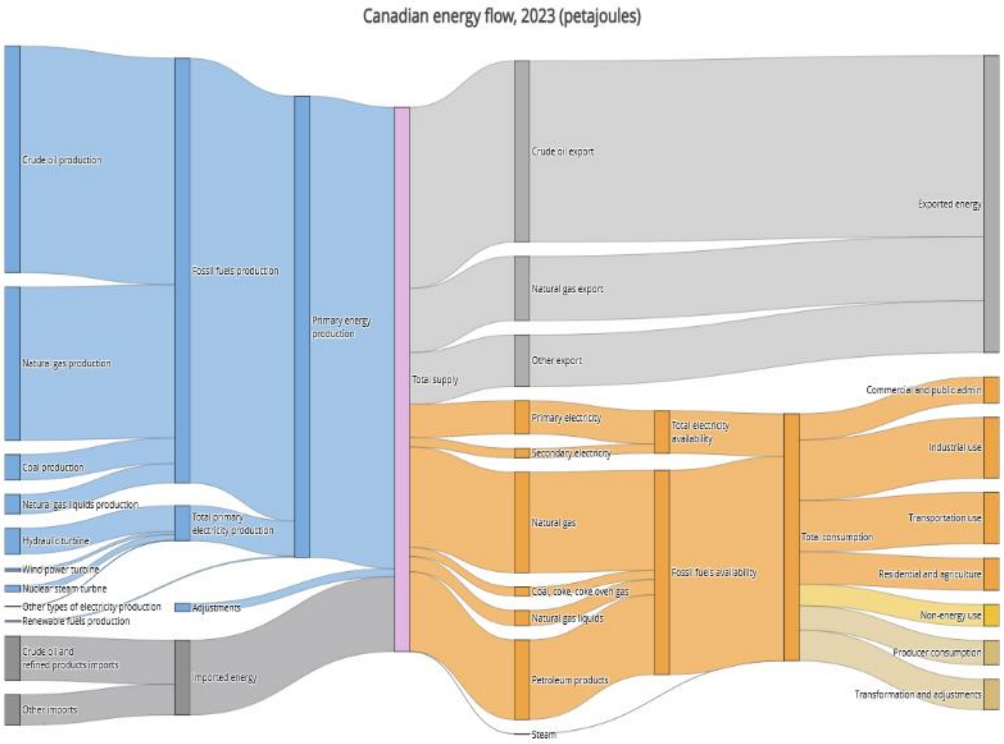
Adam Tuck – RD20 2025 Session 1 – Hydrogen Production & Transport

1. Canada’s National Hydrogen Strategy
2. Advanced Clean Energy Program
3. Hydrogen Production & Transportation R&D
4. Opportunities and Next Steps

Canadian Hydrogen Strategy

Energy Production in Canada

- **Hydroelectric Power:** Hydroelectricity provides over 60% of Canada's electricity, with 81,000 megawatts capacity.
- **Renewable Energy:** Wind, solar, and biomass sources make up 18% of Canada's electricity.
- **Nuclear Energy:** Ontario has 19 reactors which supply 15% of Canada’s electricity.
- **Oil Production:** 4th largest oil producer in the world, ~4.5 million barrels per day, mainly from Alberta's oil sands.
- **Natural Gas Reserves:** Canada has proven reserves of approximately 2 trillion cubic meters.
- **Energy Exports:** Canada is a major energy supplier to world markets, especially to the US:
  - Oil = ~3 million barrels of oil per day
  - Natural Gas: ~76 billion cubic meters annually.
  - Electricity: ~50 terawatt-hours / year, mostly hydroelectric



Source: [Canadian energy flow Sankey diagram | Canadian Centre for Energy Information]

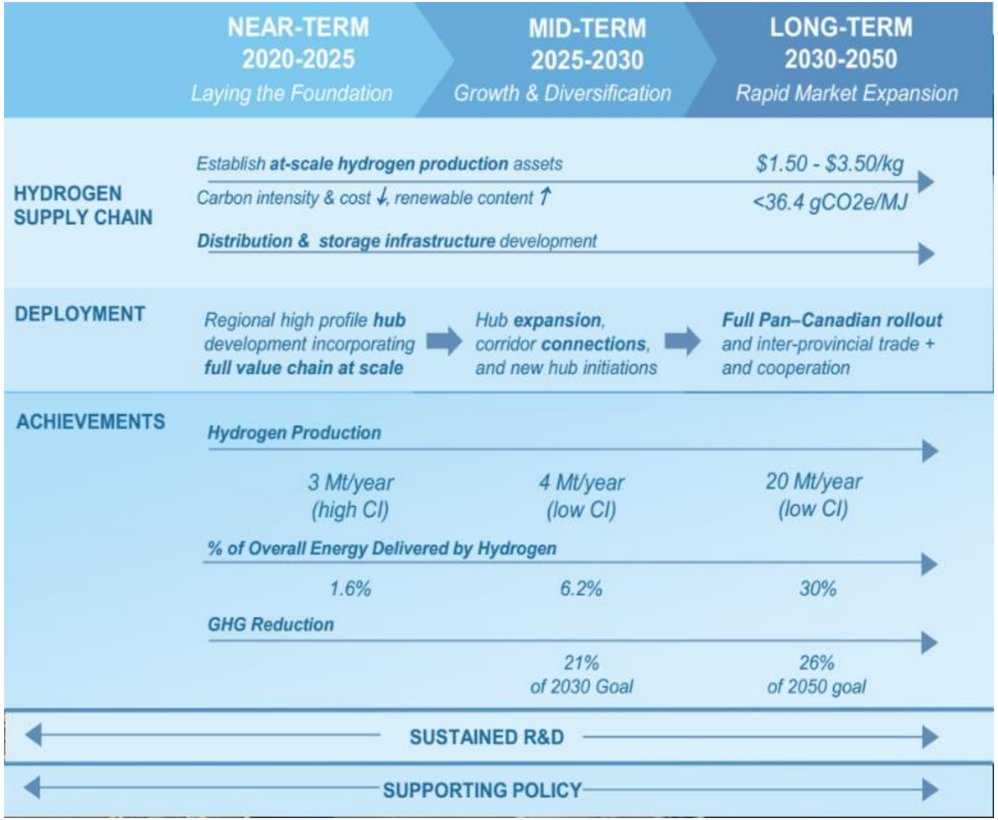
Canadian Hydrogen Strategy

National Vision & Goal

- Position Canada as a global supplier of choice for low-carbon hydrogen and related technologies.
- Achieve net-zero emissions by 2050 while creating economic growth, jobs, and export opportunities.

Strategic Priorities (2024–2026)

1. De-risk high-impact production projects.
2. Build scalable hubs and strategic corridors for key end-uses.
3. Advance codes and standards for safe deployment and trade.
4. Increase public awareness and improve market data.



Hydrogen Strategy - Opportunities

Ambitious Production Targets

- **Current production**: ~3 million tonnes/year, mostly grey hydrogen via SMR (top 10 global producer).
- **GHG reductions:** Could contribute >13% of Canada’s targets
- **Export Opportunity**: Projects positioning Canada a net exporter

Investments

- **Large investments** – could reach 3% of GDP (>$100B potential investment, 95% private)
- **Projects:** 94 Publicly announced with 5.4 MT/yr capacity
- **6 H_2 hubs:** planned across Canada (Vancouver, Edmonton, Toronto, Quebec, Atlantic, Prince George).

Resources to support H_2 economy

- **Electricity** – significant demands of 156 TWh/yr
- **Water** – 4% of total current water withdrawl for manufacturing
- **Critical Minerals** – secure supply chains

Source: Canadian Low-Carbon Hydrogen Observatory, 2024 Report

Hydrogen Strategy - Challenges

Economic Viability & Cost Gap

- Electrolytic hydrogen costs **$3–5/kg**, still **2–3× higher** than grey hydrogen from SMR with CCS (**$1.5–2/kg**)
- Need for technology cost-down and efficiency gains to meet cost targets

Infrastructure Readiness & Integration

- Coordination gaps between production sites, transport/storage, and end-use locations
- Limited hydrogen-ready infrastructure; blending pilots only up to 5% in pipelines
- Export infrastructure still in planning — deep-water port projects yet to be commissioned

Supply Chain Constraints

- Domestic manufacturing gaps for electrolyzers/components; only **1% of 18.8 GW planned WE capacity** has a tech supplier identified
- Critical minerals processing capacity (e.g., iridium, platinum, nickel) insufficient to meet projected demand

Global Uncertainty & Market Dynamics

- Various subsidies and incentives (US IRA, EU REPower, Japan GX) in place, but long term viability is unclear
- Risk of oversupply from low-cost producers (Middle East, Australia) compressing export margins

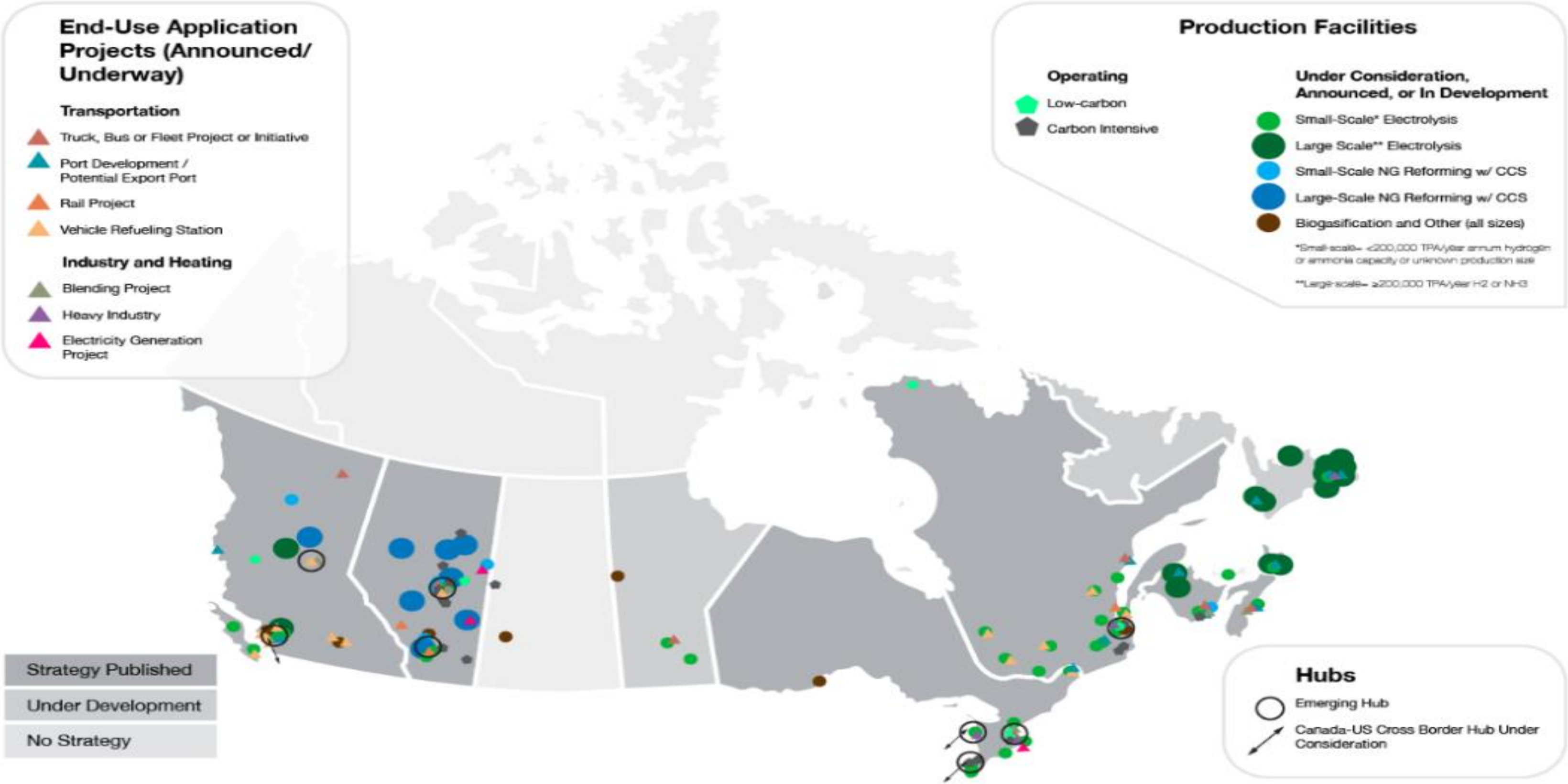
Regulatory & Standards Alignment

- Codes & Standards gaps — 22 developed, but harmonization with EU/Japan still in progress
- Certification misalignment could restrict exports & International collaboration

Public Awareness & Acceptance

- Limited understanding among the public and some industry sectors of hydrogen's safety and decarbonization potential
- Social license challenges for large-scale infrastructure projects

Hydrogen Strategy – Progress since 2020



Hydrogen at the NRC

NRC's Clean Energy Goals

- **Support the entire technology readiness scale**, from fundamental research, to technology development and scale-up, to prototyping and field testing
- Provide access to one of a kind, **large-scale facilities and testing expertise** to validate innovative energy, mining and environmental solutions
- Complete world-leading and unbiased **technology performance validation**
- Collaborate to address **emerging technology requirements** as the energy and mining sectors tackle sustainability challenges

Research facilities across Canada

Vancouver, Victoria and Penticton, BC
Optical and radio telescopes, adaptive optics, Canadian Astronomy Data Centre, batteries, fuel cells and industrial tribology

Edmonton, AB
Nanotechnology

Saskatoon, SK
Plant biotechnologies and plant-growth facilities

Winnipeg, MB
Additive manufacturing, including digital twinning and machine learning, sustainable food packaging

London and Mississauga ON
Additive manufacturing, product development, laser consolidation, micro-machining, next-generation materials discovery and development for clean energy conversion and digital manufacturing

Ottawa, ON
Aerospace, vaccines, construction, quantum, photonics, machine vision, big data analytics, metrology, materials characterization and testing, ice and coastal engineering and water resources

Montréal, Boucherville, Royalmount and Saguenay, QC
Intelligent machining, robotics, medical devices, advanced biologics analytics, biologics manufacturing, aluminium and multi-materials assembly, hybrid manufacturing (extrusions, forgings, castings)

Halifax, NS
Photobioreactors, bioprocessing, natural product chemistry, bioactive characterization, biotoxin metrology

Charlottetown, PE
Natural product and functional ingredient development

St. John’s, NL
Ocean engineering, ice and vessel management

NRC's Energy Focused Programs

Fuel Switching

- Biofuels from Waste
- Fuel-Switching Compatibility
- Mixed Fuels Transportation

Electrification

- Battery energy storage technologies for stationary and motive applications
- Supporting battery supply chains up and mid stream
- Microgrid component testing and integration
- Critical Minerals (up and mid stream; recovery)

Hydrogen

- Clean hydrogen production from renewables
- Hydrogen distribution
- Codes and Standards support

Carbon Management

- CO_2 conversion to fuels and chemicals
- CO_2 mineralization
- CO_2 transportation
- CO_2 sensing
- Efficient and low-emission heavy industry processes (mining, steel, oil & gas)
- Circularity

GHG emission reduction impact timeline

Near-term — Medium-Term — Longer-Term

CEI Program Map

Advanced Clean Energy (Mid-to-High TRL)

Clean Production (Medium TRL)

Materials for Clean Fuels Challenge (Low TRL)

Advanced Clean Energy Program

- 7-year strategic research program with >65 projects with partners from industry, academia and government
- Maximizing the impact of the Canadian clean energy sector through work on complex Canadian resources, feedstocks and materials
- Focusing on mid-to-high TRL clean energy technologies that can be applied to multiple sectors

1 - Battery Energy Storage

Supporting the emerging battery supply chain

2 - Low Carbon Fuel Switching

Fuel switching using clean fuels produced from waste

3 - Hydrogen

Supporting the production and distribution of fossil-free hydrogen

4 – Grid Integration

Validation and integration of renewables for grid resiliency

Advanced Clean Energy Program - Hydrogen

Using Canada’s clean electricity and water, enabling the production and distribution of hydrogen to build the supply chain

Production

Technology development for the advancement of fossil-free H2

- Testing platforms for new materials and membranes in electrolyzers and electrolyzer components

Distribution

Development and evaluation of technologies to get H2 to end-users

- H2 storage codes and standards and data collection for system optimization
- Support for materials evaluation for pipeline blending and refuelling stations

Conversion

Efficient and clean H2 conversion

- Fuel-cells for stationary and end-use agnostic studies

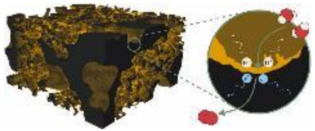
Strategic Support

Decision-making tools

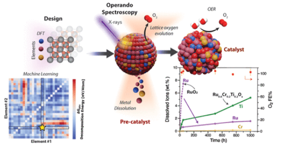
- Codes and standards gaps analysis across the supply chain
- Lifecycle analysis for various H2 production pathways

Hydrogen Production Technologies - PWMWE

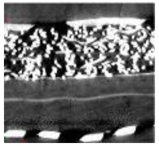
Fundamental understanding



Catalyst layer microstructure



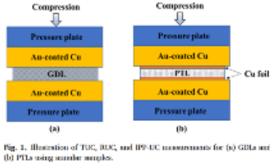
ML-aided catalyst identification



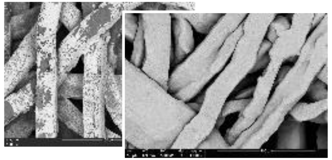
In-operando cell for µXCT

Journals and IP

Innovative components and devices



QC devices

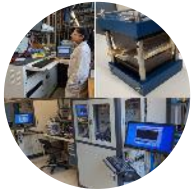


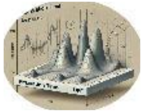
New PGM coating methods

Critical component manufacturing

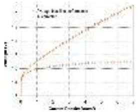
Publications & IP

SOTA facility for industry support





In-situ diagnostic: Modelling to develop Digital-Twin & improve electrolyzer efficiencies



IEA-Task30: Participation in round-robin performance and durability testing

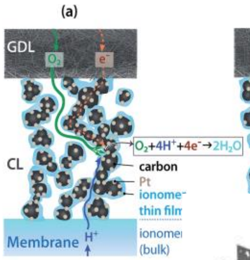
Hydrogen Production Technologies - AEMWE

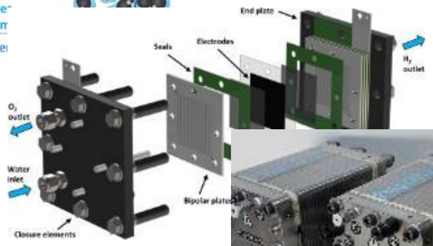
NRC's goal is to work with industry and academia to commercialize low cost H2 production from AEME by integrating novel materials

Material Developers → Component Manufacturer → Stack Technology Integrator → System demonstration and commercialization

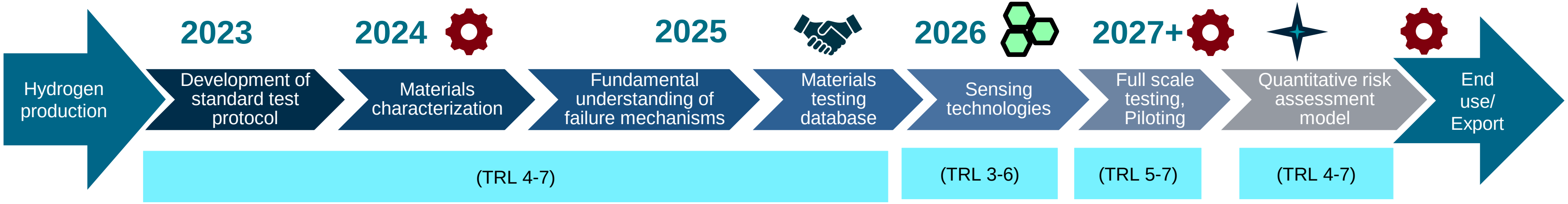
Focus Areas:

- Materials (Catalysts) evaluation and integration
- MEA/Cell benchmarking and validation
- High performance MEA with novel architecture and catalysts integrated
- MEA Fabrication with industrial scalable processes
- Failure mechanism understanding





Hydrogen Transport & Infrastructure



- ✓ Enabled Enbridge to implement hydrogen blend in Gatineau, Québec network.
- ✓ Supported the engineering assessment of world's largest blended network.

ENBRIDGE · énergir · SFU · DALHOUSIE UNIVERSITY · UBC · C-FER Technologies, A SUBSIDIARY OF ALBERTA INNOVATES · CSA GROUP · EVRAZ · UNIVERSITY OF ALBERTA

Industrial application · AI-assisted tools · SME/MNE off-take · Codes and standards

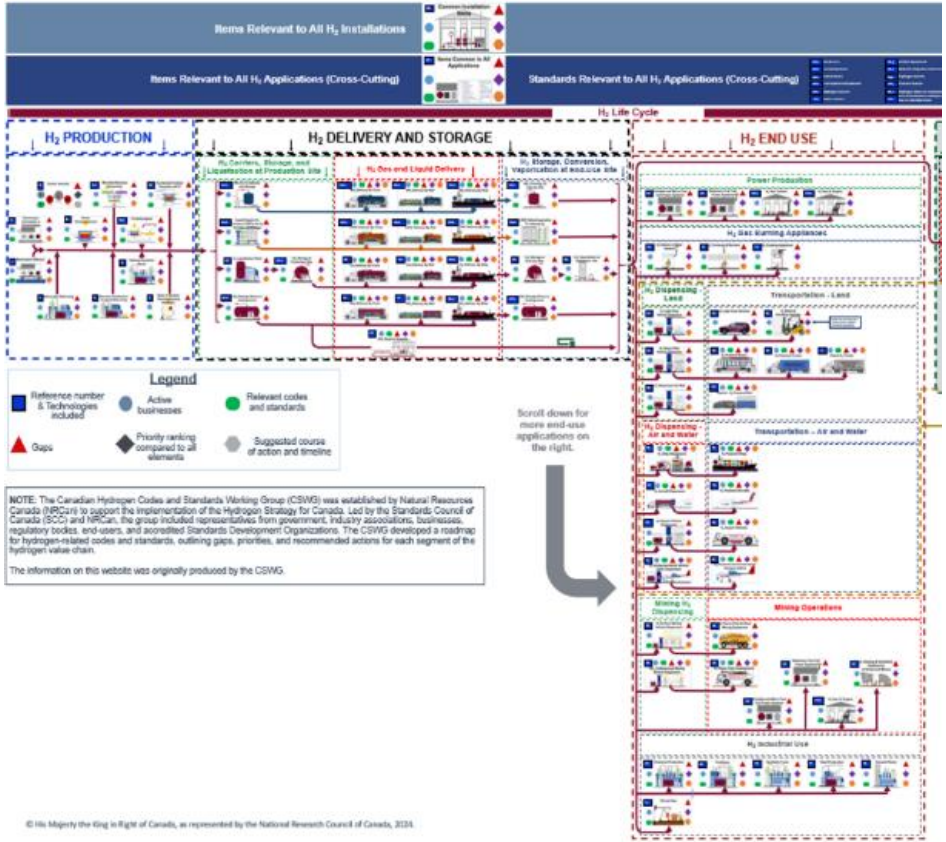
Strategic Support for the Hydrogen Ecosystem

H2 Lifecycle Assessment

- **Objective** - Develop a globally acccepted methodology to assess the carbon intensity for policy support, trade and reporting
- **Focus** - Hydrogen production pathways relevant to Canada, Conversion to ammonia as a hydrogen carrier

H2 Codes and Standards

- **Objective** - Gain understanding on the gaps in codes and standards existing across the hydrogen value chain and define a path to address them
- **Focus** - Gap analysis, Work with collaborators to establish priorities and path forward, Establish publicly available website



Project Examples

PWMWE – Novel PGM Coating Methods

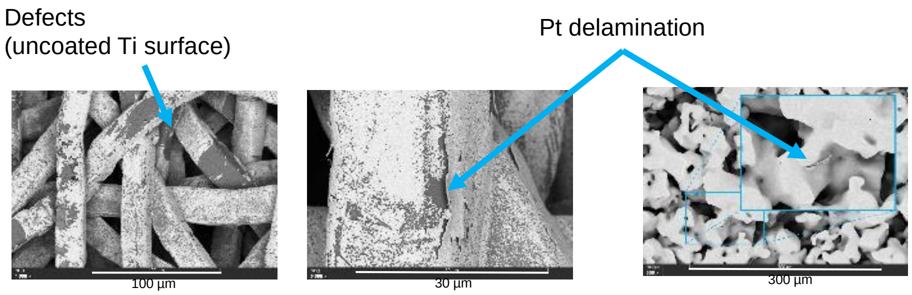
Project Goals:

- Selective activation and deposition,
- No sophisticated equipment required
- Minimized PGMs usage,
- Produce strong metal-to-metal bonds,
- Enable uniform deposition on complex shapes,
- No hazardous pre-treatment,
- No intermediate strike layers

Result

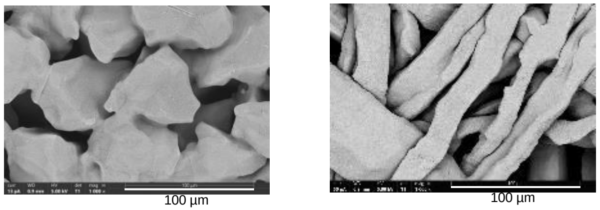
- Process simplification enabling an estimated cost saving of 30-40%
- High quality coating results in high performance and durability

Electroplating PVD

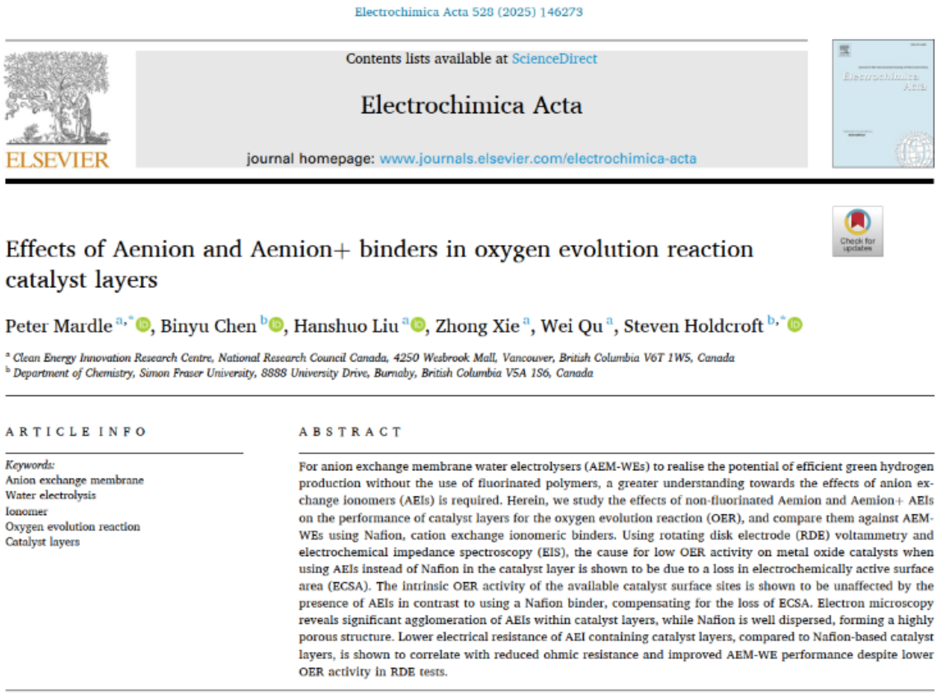


As received commercial Pt-coated Ti PTL

NRC Method



AEM Catalyst Layer Development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Effects of Aemion and Aemion+ binders in oxygen evolution reaction catalyst layers

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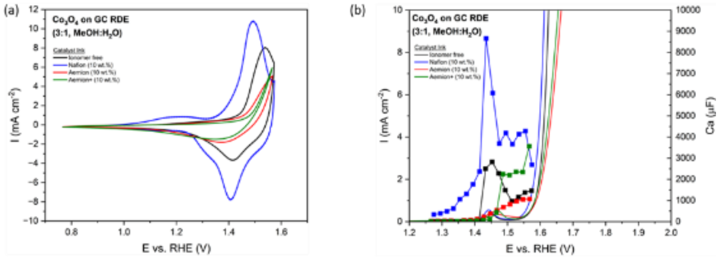
ABSTRACT

For anion exchange membrane water electrolysers (AEM-WEs) to realise the potential of efficient green hydrogen production without the use of fluorinated polymers, a greater understanding towards the effects of anion exchange ionomers (AEIs) is required. Herein, we study the effects of non-fluorinated Aemion and Aemion+ AEIs on the performance of catalyst layers for the oxygen evolution reaction (OER), and compare them against AEM-WEs using Nafion, cation exchange ionomeric binders. Using rotating disk electrode (RDE) voltammetry and electrochemical impedance spectroscopy (EIS), the cause for low OER activity on metal oxide catalysts when using AEIs instead of Nafion in the catalyst layer is shown to be due to a loss in electrochemically active surface area (ECSA). The intrinsic OER activity of the available catalyst surface sites is shown to be unaffected by the presence of AEIs in contrast to using a Nafion binder, compensating for the loss of ECSA. Electron microscopy reveals significant agglomeration of AEIs within catalyst layers, while Nafion is well dispersed, forming a highly porous structure. Lower electrical resistance of AEI containing catalyst layers, compared to Nafion-based catalyst layers, is shown to correlate with reduced ohmic resistance and improved AEM-WE performance despite lower OER activity in RDE tests.



1. Aemion and Aemion+ ionomers do not inhibit the kinetics for the OER but do lower the ECSA.

2. Nafion is the best ionomer in half-cell tests although other factors (such as a higher electrical resistance of catalyst layers) and sufficient ionic conductivity in 1M KOH means AEM-WE performance not affected much by ionomer choice. Likely a greater influence from catalyst layer resistances.

Hydrogen Transport Metallurgy

npj | materials degradation — Article

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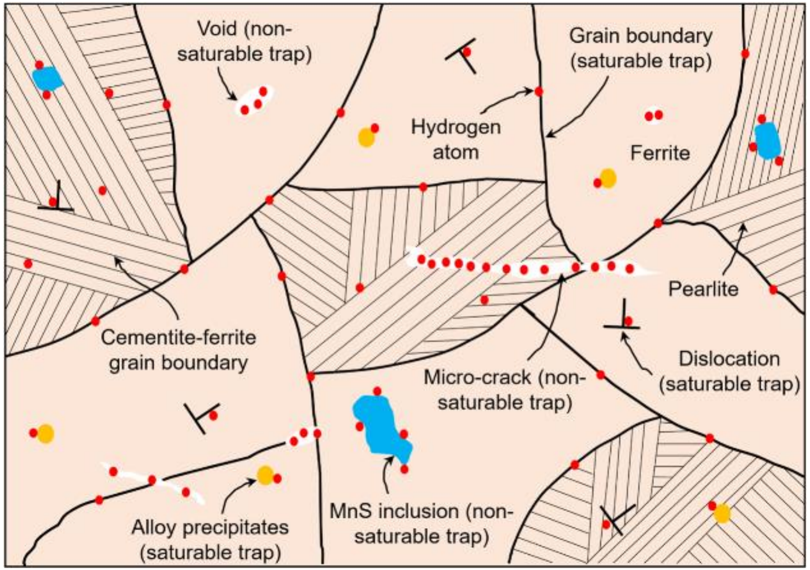
Effect of microstructure on hydrogen permeation and trapping in natural gas pipeline steels

Check for updates

Aminul Islam[1,2], Qidong Li[2], Emma Storimans[1], Kay Ton[1], Tahrim Alam[3] & Zoheir N. Farhat[2]

This study examines hydrogen permeation and trapping in three types of natural gas pipeline steels from different decades in Canada—modern, vintage, and legacy steels. Electrochemical permeation experiments were conducted to measure the diffusion coefficient, subsurface concentration, and trap density of hydrogen. The results were analyzed to evaluate the susceptibility of these steels to hydrogen embrittlement and to understand the effects of hydrogen on their mechanical properties. Vintage steel exhibited 50% higher steady-state permeation current and 97% greater effective diffusivity compared to modern steel, while legacy steel showed intermediate values. Hydrogen diffusion increased with grain size and pearlite content but decreased with dislocation density. Modern steel demonstrated the highest resistance to hydrogen permeation due to its finer grain structure and higher dislocation density. This study provides essential insights into the diffusion behavior and trapping mechanisms of hydrogen in natural gas pipeline steels, enhancing the understanding of material performance under hydrogen exposure.



Summary

Opportunities:

- **CO_2 Reduction:** Up to 109 Mt/year globally by 2050 from Canadian low-carbon H_2 exports; 17–69 Mt/year domestically.
- **Economic Growth & Jobs:** Multi-billion-dollar annual market; tens of thousands of skilled jobs
- **Energy Security:** Diversified supply chains for allies in Europe and Asia.
- **Innovation:** Advances in materials, transport, and standards benefiting the wider clean energy sector.

Areas for Collaboration:

- **Production** – low cost PTL coatings; durable, low-cost AEM MEAs.
- **Transport** – Validate safe pipeline blending; develop coatings & sensors; ready export carriers (ammonia, methanol).
- **Ecosystem** – Align codes & standards; harmonize certification, robust lifecycle analysis.
- **Global Engagement** – Joint R&D, tech validation, and supply chain partnerships with RD20 members.

Collaboration is key to closing hydrogen's cost and infrastructure gaps, delivering real-world benefits globally.

Thank you

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