Hydrogen and the Transition to Net-Zero Energy Systems

David B. Layzell, PhD, FRSC.

Energy Systems Architect, The Transition Accelerator
Professor & Director, Canadian Energy Systems Analysis
Research (CESAR) Initiative, U. Calgary,
E: dlayzell@ucalgary.ca; W: www.transitionaccelerator.ca

Adnan Khan, Energy Systems Analyst
Hamid Rahmanifard, Energy Systems Analyst
Song Sit, Senior Assoc., CESAR

Mark Lea-Wilson, ERH2 H2 Lead (Supply, Heat & Power)
Jacob Lamb, ERH2 H2 Lead (Transport)
Chris Bayley, W Canada H2 lead

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NET-ZERO EMISSIONS BY 2050

...COMMITTED TO BY CANADA, USA AND DOZENS OF OTHER COUNTRIES

The Transition Accelerator

- How can Canada ‘win’?
- What are the best transition pathways?

Existing Energy System

Net-Zero Energy System

Why Hydrogen ($H_2$)?

1. Some sectors need chemical, not electrical energy carriers
   - HD transport
   - Heavy Industry
   - Space Heating (esp. cold regions, large buildings)

2. Complements low carbon electricity generation

3. Enhances biofuel production
Towards a New Hydrogen (H₂) Economy

H₂ Today (Can: ~8.2 kt H₂/d)

GRAY H₂

Fossil Fuels

H₂

CO₂ (a GHG)

Industrial Feedstocks

Fertilizer for Agriculture

Fuels for Transportation

Materials & Chemicals

H₂ in a New, Net-Zero Energy System

BYPRODUCT H₂

Chlor-alkali Plants, etc

GREEN H₂

Renewables

Nuclear

H₂ Fuel

Transport

Buildings

Industry

Power

_export

Industrial Feedstock

Fossil Fuels

Biomass

H₂O

BLUE H₂

CO₂ Sequestered

O₂ H₂O

The Transition Accelerator

from Layzell et al. 2020
What are the Value Chains in a New Hydrogen Economy?

**Production**
- Low C power
- Water
- Biomass
- NG
- Oil
- Gasifier/Reformer
- CO₂
- Pipeline
- Utilization/storage
- Electrolyzer

**Oxy-Firing**
- Natural Gas
- CO₂
- Utilization/storage
- Cement, Power
- Products

**Upgrading & Transporting**
- Pipeline
- Blending (up to 20% v/v)
- H₂ Pipeline
- Tube Truck

**Heat & Power Generation**
- Grid
- Power Gen
- Fuel H₂

**Orig. Equip. Mfg. (OEM)**
- Fuel Station
- Exporting

**Transportation**
- Export Markets
Canada: Among the World’s Lowest cost producers of ‘Blue’ & ‘Green’ H₂

From fossil fuels (NG) coupled to carbon capture and storage (CCS)

From water electrolysis using very low C electricity (wind, PV, hydro, nuclear)

Adapted from Asia Pacific Energy Research Centre. 2018. Perspectives on H₂ in the APEC Region. (Figure 3.4) https://aperc.ieej.or.jp/file/2018/9/12/Perspectives+on+Hydrogen+in+the+APEC+Region.pdf
Canada has low-cost Blue & Green H₂... But what about the environmental footprint?

Life Cycle GHG Intensity

~3 kg CO₂e/kg H₂

Fossil Fuels

Biomass

BLUE H₂

CO₂

Sequestered

Industrial Feedstock

Fertilizer for Agriculture

Fuels for Transportation

Materials & Chemicals

ByProduct H₂

Chlor-alkali Plants, etc

GREEN H₂

Renewables

Nuclear

H₂ Fuel

Transport

Buildings

Industry

Power

Export

Life Cycle GHG Intensity

~0.8 to 3 kg CO₂e/kg H₂

For more details:
https://transitionaccelerator.ca/wards-net-zero-energy-systems-in-canada-a-key-role-for-hydrogen/

Assumes upstream CH₄ emissions (as CO₂e) = 19% of combustion emissions. This must be reduced!

Reduction in Life cycle C Emissions

80% to 95%

67% to 90%
What Markets for Hydrogen are Most Promising?

- **Heavy Transportation:** Offers the market where H\(_2\) is most likely to be economically viable in the short to medium term.

- **More Challenging:**
  - Space/ water heating
  - Industrial Heating
  - Power generation

... but H\(_2\) is likely to be the best net-zero choice for these sectors.
Retail Cost Components for H₂ as a Transportation Fuel

Retail Cost Estimates for H₂ Fueling Station within 5 km of Supply

**NOTE:**
1. Fueling station size has a major impact on the retail cost of delivered H₂:
   -➢ To be economically sustainable, 2+ t H₂/d is needed.
     ➢ =~80+ buses/stn. OR ~40 class 8 trucks/stn
2. While H₂ production cost is important, the other costs in the value chain are of equal or greater importance:
   -➢ Preparation and Delivery
   -➢ Fuel station
   ...AND the distribution technologies also impact the fueling station cost
How to Build a New Hydrogen Economy
The H₂ Problem...

It's a gas, therefore more difficult to move and store than liquids, especially in small quantities.

**MUST BRING TOGETHER:**
- Low-cost waste, blue or green H₂;
- Substantial nearby markets for the H₂ (esp. transport and heating fuel markets)
- Ability to connect the two
- Scale of supply/demand where the economics works without sustained public investment;
- Engaged industry, governments and academics

We must create new, self-sustaining VALUE CHAINS connecting demand to supply...
Towards a New H₂ Value Chain in Alberta

1. ‘Piggy-back’ on low cost industrial blue H₂ production.
2. Pipeline H₂ to new fuel markets
3. Rapidly grow H₂ demand
4. Attract H₂-using industries & OEMs

Existing or New Industrial Feedstock Demand

H₂ Industrial Scale
‘Blue’ H₂ Production
✓ 100’s t H₂/day
✓ ~$1.50/kg H₂

Pipeline

H₂

LH₂ Production
✓ 10+ t LH₂/d
✓ Adds ~$3+/kg
✓ ~4 t LH₂/truck
✓ HFCE ready

CO₂

Strategically located stations to build demand & justify future pipeline connection (fuel for station needs subsidy)

With C taxes going to $170/t CO₂, price target could be higher.
Hydrogen in Alberta

Alberta currently produces:
- ~5,400 t H₂/day
- 2/3rd of Canadian production
- For use as industrial feedstock
  - Fertilizer production
  - Oil upgrading/refining
  - Chem & material production

The Alberta Industrial Heartland (AIH)

Estimated Annual Production in AIH:
- Total: ~2250 t H₂/d
- Blue: ~937 t H₂/d

New Blue H₂ initiatives
- May 2021: Suncor/ATCO for ~2027
- June 2021: Air Products for ~2024
- July 2021: Scotford CO₂ infrastructure
- Aug 2021: Petronas-Itochu H₂/NH₃ export
- Sept 2021: Mitsubishi-Shell Canada H₂/NH₃
- Nov. 2021: Northern Petrochem. Corp. H₂/NH₃
Edmonton’s Markets for Fuel Hydrogen

...on two corridors

Transportation:
~670 t H₂/d

Building Heating:
~1500 t H₂/day

+ Export
Power & Control in the New H₂ Value Chain

4. Fuel Supply
- Many companies want to provide fuel H₂ – highly competitive;
- Public subsidies need to be tied to prices for fuel H₂ until a competitive economy exists.

3. Fuel Delivery and Retail:
- In our existing energy system, this has been the main profit centre;
- However, for the key stakeholders to drive this transition, they will need to have confidence in future fuel pricing;
- Public funding to this sector should ensure that key stakeholder needs are met.

2. OEMs & Retrofit companies
These tend to be global companies and we are competing for their attention to build vehicles that meet the needs of our markets. Most important is that the key stakeholders want to buy.

1. The Key Stakeholders:
- They will eventually pay for the whole value chain;
- They need to be engaged and their interests addressed from the beginning
- [This is a challenge since they are highly competitive and tend to not work collectively]
Projects being Deployed

**AZETEC**
- Design, build, pilot 63.5t GVW HFCE trucks for Edmonton-Calgary route
- ETA: Jan 2023

**AZEHT**
- Demonstrate two HFCE transit buses in Edmonton & Strathcona
- ETA: August 2022

**CP**
- Hydrogen-powered line-haul freight locomotive
  - Converting three diesel-electric locomotives to hydrogen fuel cell-electric locomotives
  - Two hydrogen fueling stations
  - ETA: 2022

**H₂-DIESEL DUAL FUEL TECHNOLOGY**
- Multiple projects to develop and deploy HD2F on HD trucks;
- Important ‘bridge’ technology to creating fueling station demand for H₂.
- ETA (Hydra Energy): 2022
HYDROGEN TRUCK ROADSHOW

Hydra Dual fuel Truck (Avail: now)

Hyzon FCE Truck (Avail: Q3, 2022)

Nikola FCE Truck (Avail: Q4, 2022)

Hyundai FCE Truck (Avail: ??)

To provide carriers & municipalities ‘hands-on’ experience with:

- H₂-diesel dual fuel:
- H₂ Fuel cell electric

HYDROGEN FUELING STATIONS

To support AZETEC, AZEHT and HD2F pilots and Demonstration Projects

ETA: 2022

METHANE PYROLYSIS PROJECTS

CH₄ → 2H₂ + C

Natural Gas

Carbon Black

- Rubber tires
- Paints
- ...?

FORT SASKATCHEWAN HYDROGEN BLENDING PROJECT

5% H₂ blending into a portion of the natural gas distribution system in Fort Saskatchewan, AB
Magnitude of the Opportunity
Magnitude of the Opportunity / Challenge

A. Alberta Transportation Fuel Market
B. Provincial Natural Gas Demand
C. Export by pipeline
D. Export by ship

Assumes
• 2018 demand
• Any increases in demand with population/GDP growth offset by efficiency / conservation
A. Alberta Transportation Fuel Market

**Alberta (2017)**

**Diesel**
- % TO H₂: 80%
- Drive Train Efficiency (J H₂/J Diesel): 0.86
- H₂ Demand (PJ H₂/yr): 195

**Gasoline**
- % TO H₂: 20%
- Drive Train Efficiency (J H₂/J Gasoline): 0.56
- H₂ Demand (PJ H₂/yr): 26

**Implications...**

**Blue H₂ Production**
- 4277 t H₂/d
- 79% incr. in AB H₂ production
- ~11 new 400 t H₂/d SMR or ATR
- CCS: 13 Mt CO₂/yr
- WTW GHG red’n: 25 Mt CO₂/yr

**Fueling Stations**
- 428 stations @ 10t H₂/d/station
- Many pipeline connected
B. NG Decarbonization for Use in Alberta

**Alberta (2018) NG Production**

- **Market Fraction to H₂ (PJ NG/yr)**
- **H₂ Blending**
- **H₂ Demand (PJ H₂/yr)**

**Implications...**

- **Blue H₂ production**
  - 19,335 t H₂/d
  - 358% incr. in AB H₂ production
  - 48 new 400 t H₂/d SMR or ATR
  - CCS: 60 Mt CO₂/yr
  - LC GHG red’n: 40 Mt CO₂e/yr

- Start with H₂ blending up to 20%;
- Then shift to pure H₂ with infrastructure change
C. Export by Pipeline

ALBERTA (2018)

NG PRODUCTION

POTENTIAL NEW NA FUEL MARKETS FOR HYDROGEN (E.G. DIESEL ALTERNATIVE) (PJ H₂/yr)

Blue H₂ production

- 25,900 t H₂/d
- 480% incr. in AB H₂ production
- 65 new 400 t H₂/d SMR or ATR
- (SAGD oil sands could be also converted to blue H₂)
- CCS: 81 Mt CO₂/yr

Green H₂ production: From dedicated wind → H₂ (@ 38% CF):

- 25,900 t H₂/d
- 147 GW new wind generation
- 87X current wind gen cap in AB
- ~24,500 large (6 MW) wind turbines, dedicated to H₂ prod’n
- Require ~85 Mm³ water/yr (<51% of water use in Calgary)

California wants Green Hydrogen

IMPLICATIONS

Exported to other Jurisdictions: 80%
D. Moving H₂ to Asia

Market by 2030: over 8000 t H₂/d

Fuel cells or combust

NH₃

H₂

LH₂ Ship

Ammonia Ship

NH₃

H₂

Liquefaction

Train

H₂/Pipeline

H₂/N₂ Pipeline

H₂

Train

H₂

Liquefaction

NH₃

NH₃

H₂

H₂

H₂

Air

NG

CO₂

Geological Storage

Auto-Thermal Reforming

Haber Bosch

H₂

H₂

H₂

BC, Alberta and/or Sask.

BC

Pacific

Japan or S Korea

Japan

South Korea

Image from Google Earth

Edmonton

Prince Rupert

Edmonton
Conclusions

- Many nations of the world, including Canada, are committed to transitioning to net-zero emission energy systems;
- Canada is poised to lead this transition given its ability to produce, use & export low-carbon (Blue & Green) hydrogen;
- The focus needs to be on H₂ Hubs and corridors;
- We need to start now!