
# Hydrogen and the Transition to Net-Zero Energy Systems

Feb 17, 2021

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# Outline

1. Net-zero emissions: the role for hydrogen
2. The economics and environmental footprint of low carbon hydrogen production
3. Towards a vibrant hydrogen economy: The HYER Hub
4. Magnitude of the opportunity & challenge over the next 10 years
5. Conclusion & Discussion

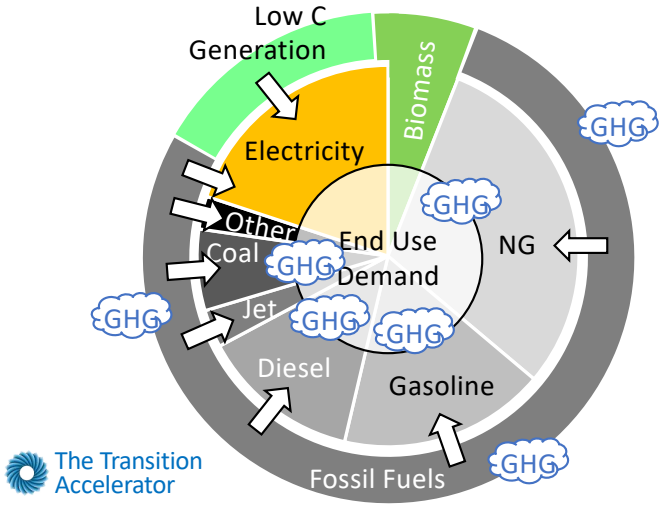
# Net-Zero Emissions by 2050

## ...Committed to by Canada and 72+ other Countries*

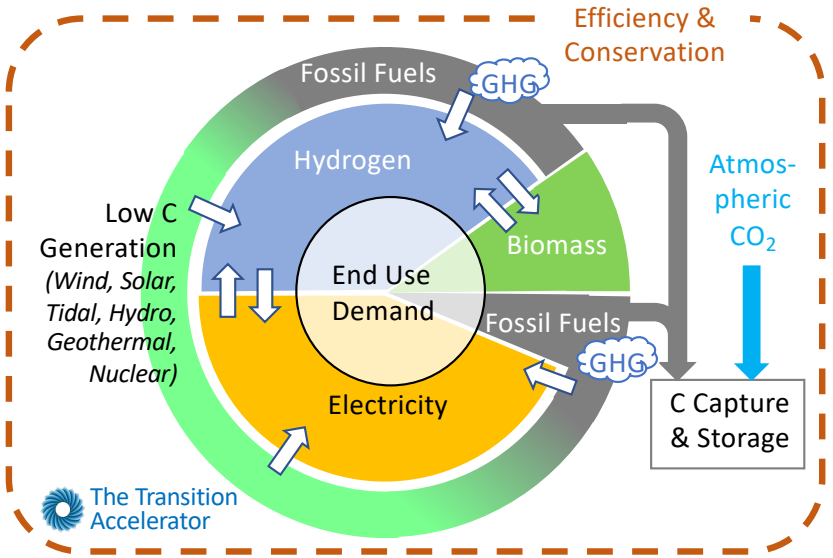
The Transition Accelerator | L'Accélérateur de transition

- *How can Canada 'win'?*
- *What are the best transition pathways?*

### Existing Energy System




### Net-Zero Energy System




* https://sdg.iisd.org/news/73-countries-commit-to-net-zero-co2-emissions-by-2050/

# Net-Zero Emissions by 2050

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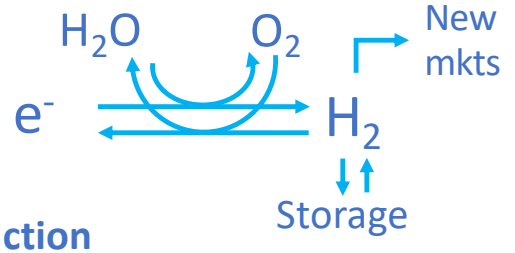
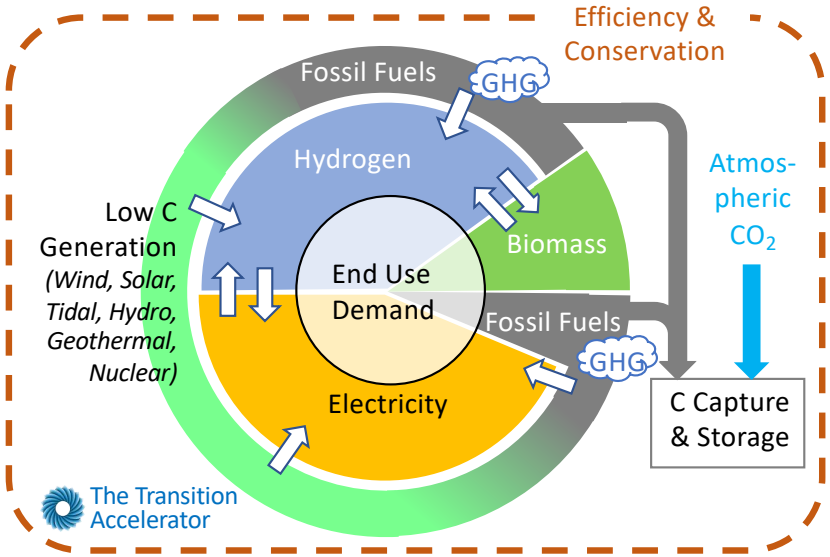
## Why Hydrogen ($H_2$)?

1. **Some sectors need chemical, not electrical energy carriers**
   - **Freight transport**
   - **Heavy Industry**
   - **Space Heating** *(esp. cold regions, large buildings)*
2. **Complements low carbon electricity generation**

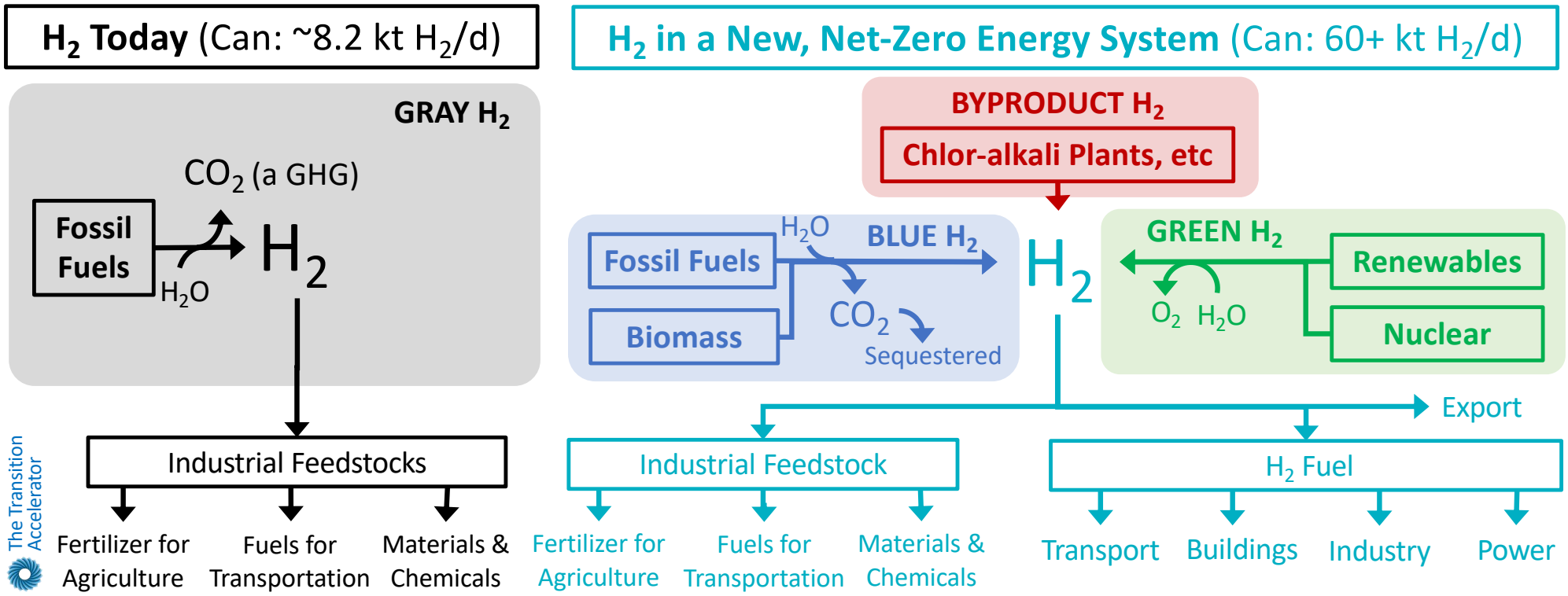



3. **Supports biofuel production**
4. **More resilient, interconnected energy system**
   *(One, not three energy systems of today)*

Net-Zero Energy System

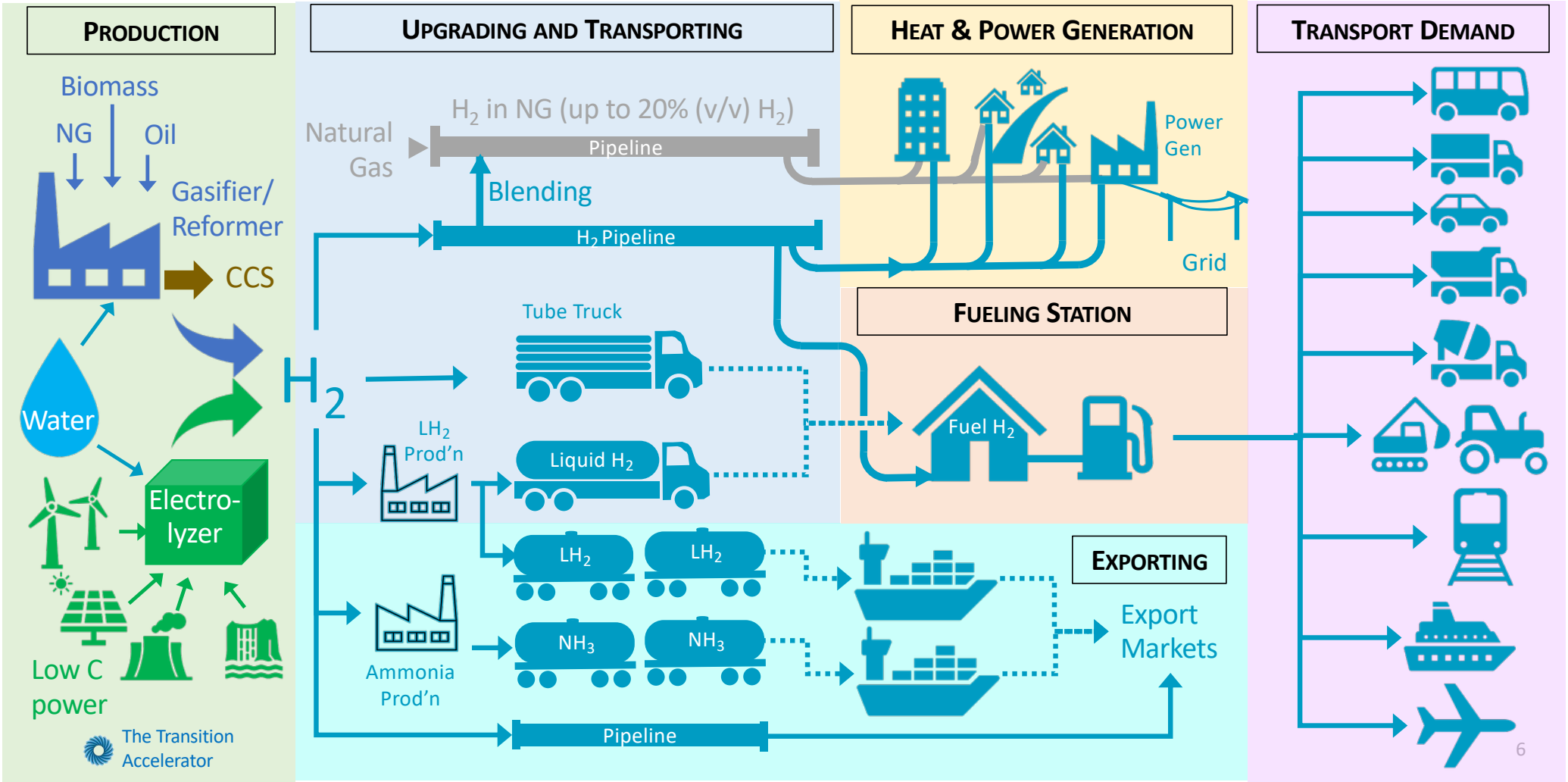


# Towards a New Hydrogen ($H_2$) Economy




from Layzell et al. 2020

# Key Value Chains in a Hydrogen Economy



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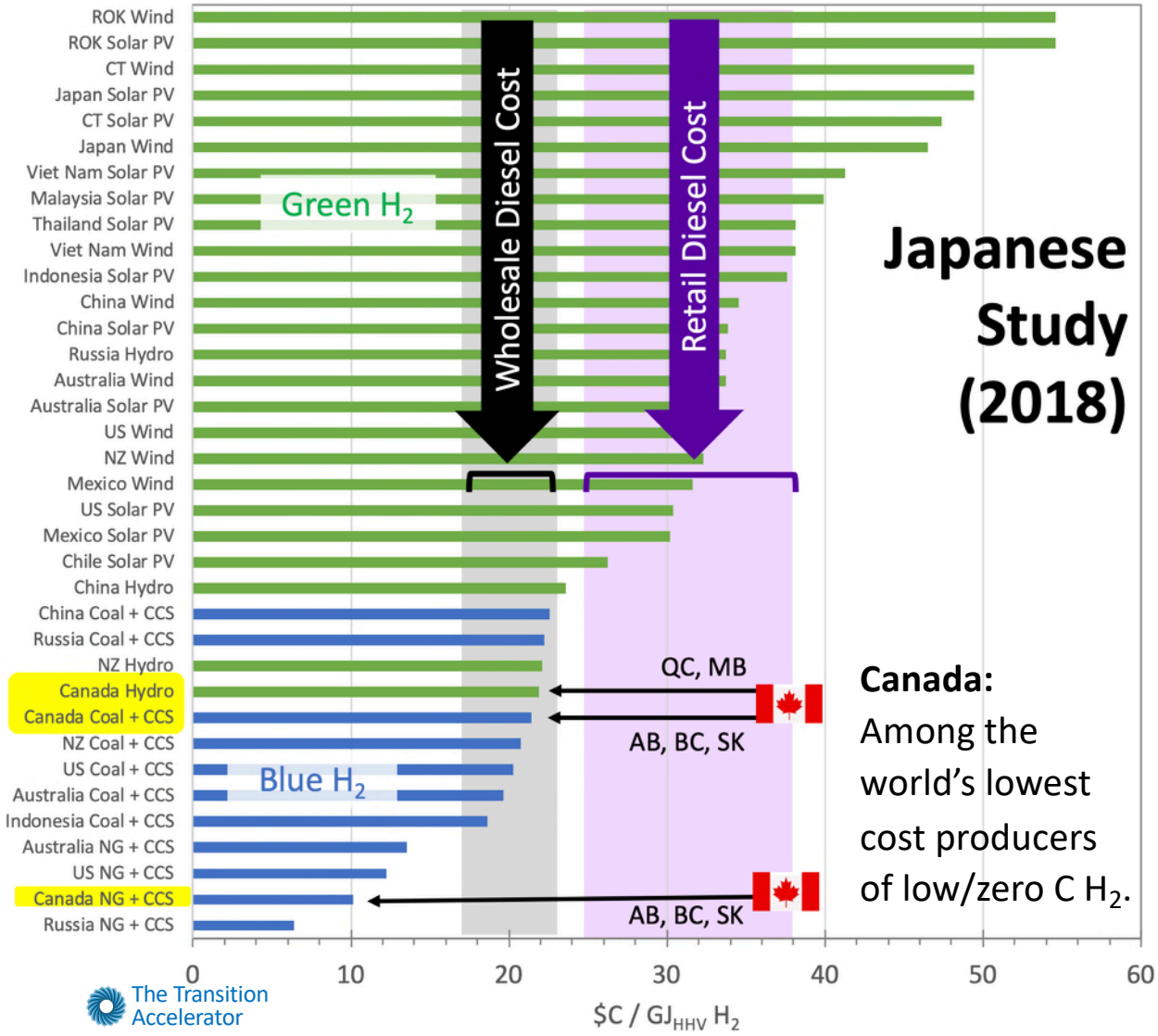
# Canada: Among the World's Lowest cost producers of 'Blue' & 'Green' $H_2$

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

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

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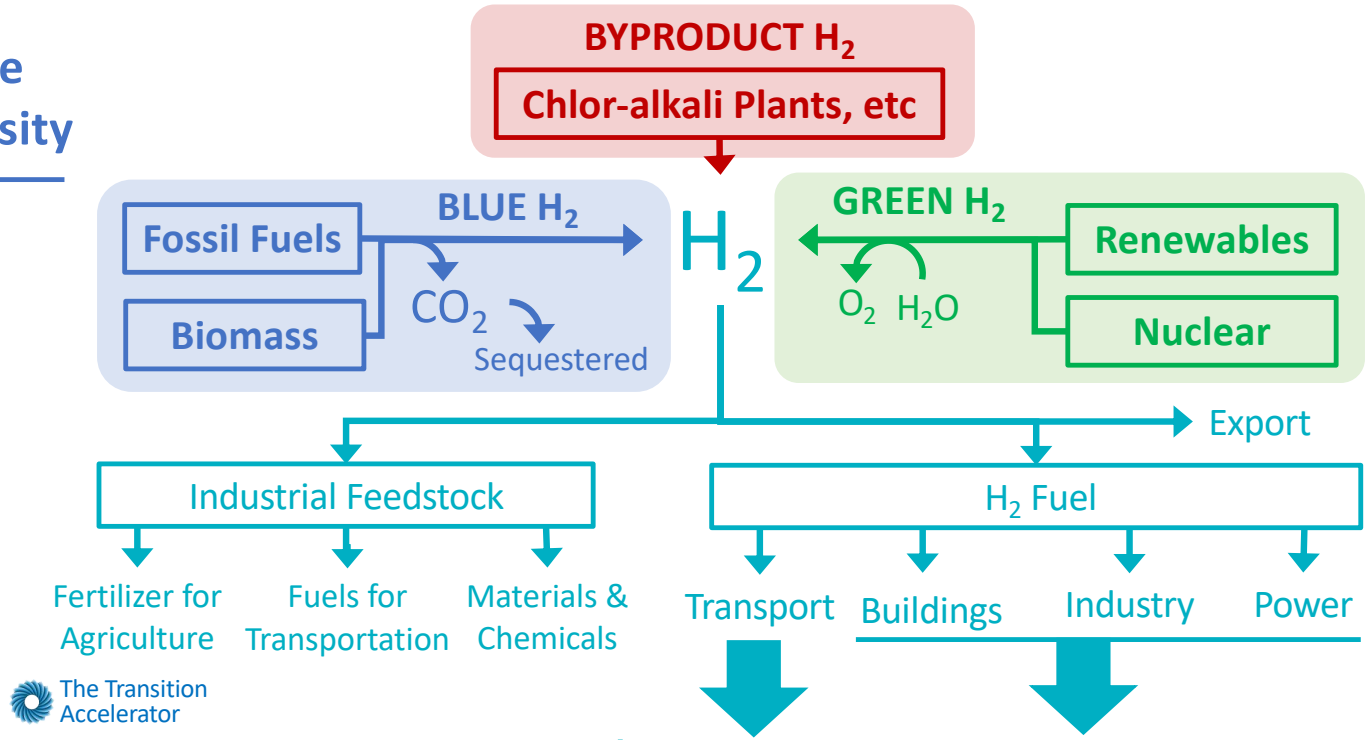
Adapted from Asia Pacific Energy Research Centre. 2018. Perspectives on $H_2$ in the APEC Region. (Figure 3.4) https://aperc.ieej.or.jp/file/2018/9/12/Perspectives+on+Hydrogen+in+the+APEC+Region.pdf

# Canada has low-cost Blue & Green $H_2$…
## *But what about the environmental footprint?*




**Reduction in Life cycle C Emissions**

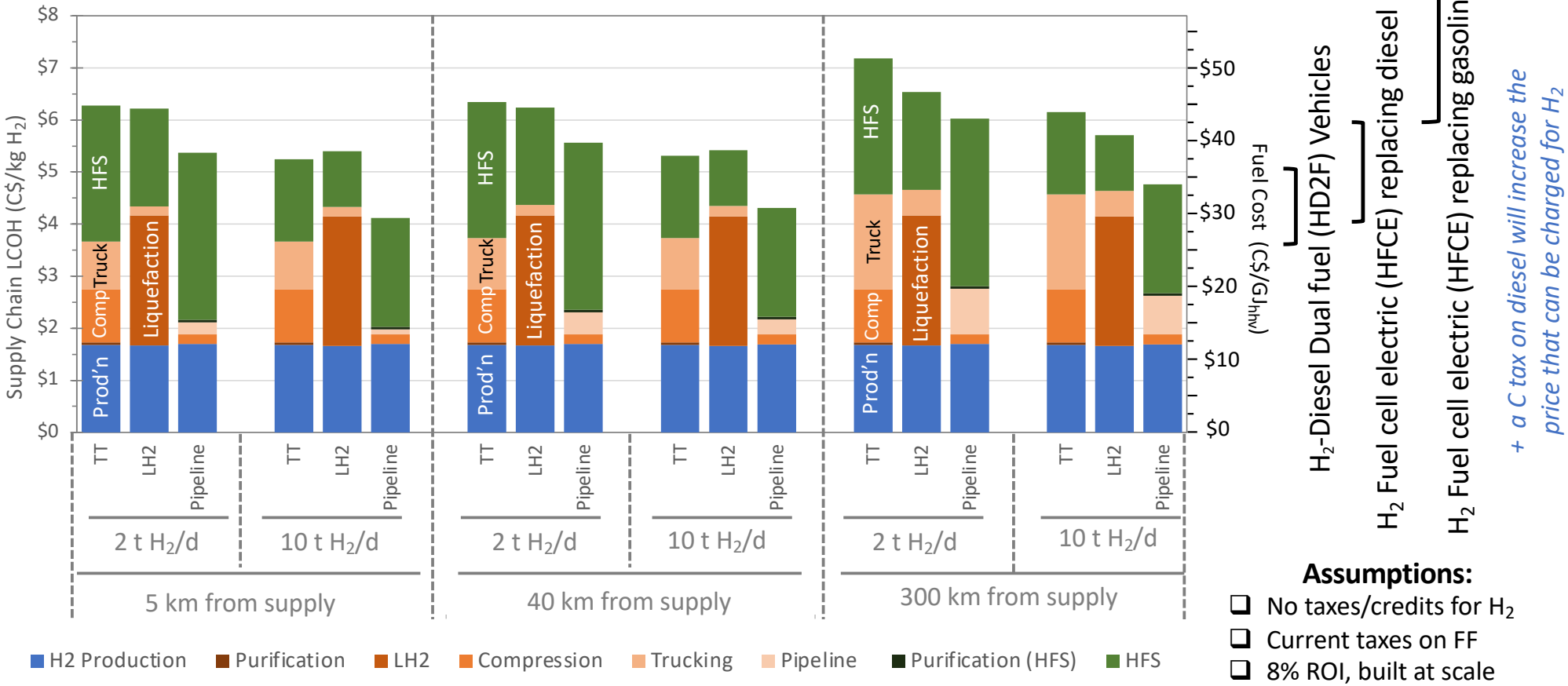
80% to 95%

67% to 90%

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

# The Cost of Blue $H_2$ at a Fueling Station (HFS)

For price parity with existing ICE vehicles




**Assumptions:**

- ❑ No taxes/credits for $H_2$
- ❑ Current taxes on FF
- ❑ 8% ROI, built at scale

Calculations adapted from https://hdsam.es.anl.gov/index.php?content=publications

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# What is Needed to Build New $H_2$ Energy Systems?

Challenge with Hydrogen:

- ❑ Its a gas: more difficult to move and store than liquids, especially in small quantities

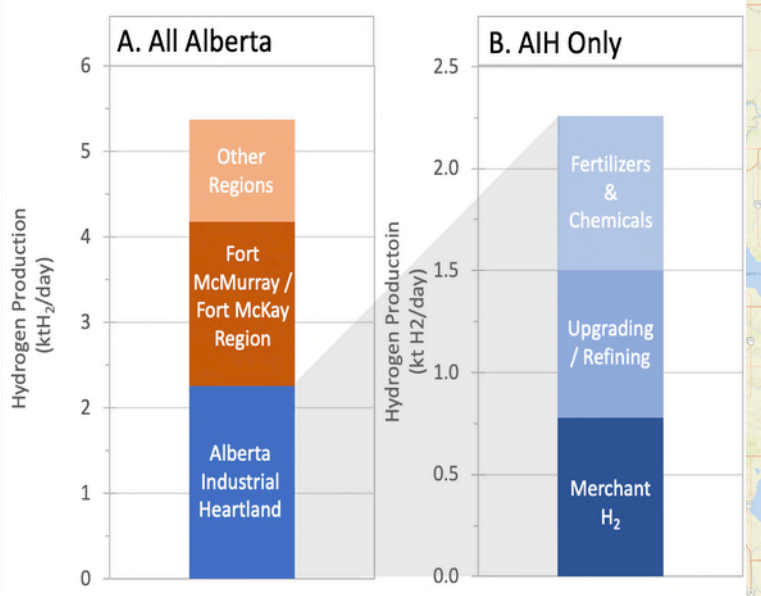

## MUST BRING TOGETHER:

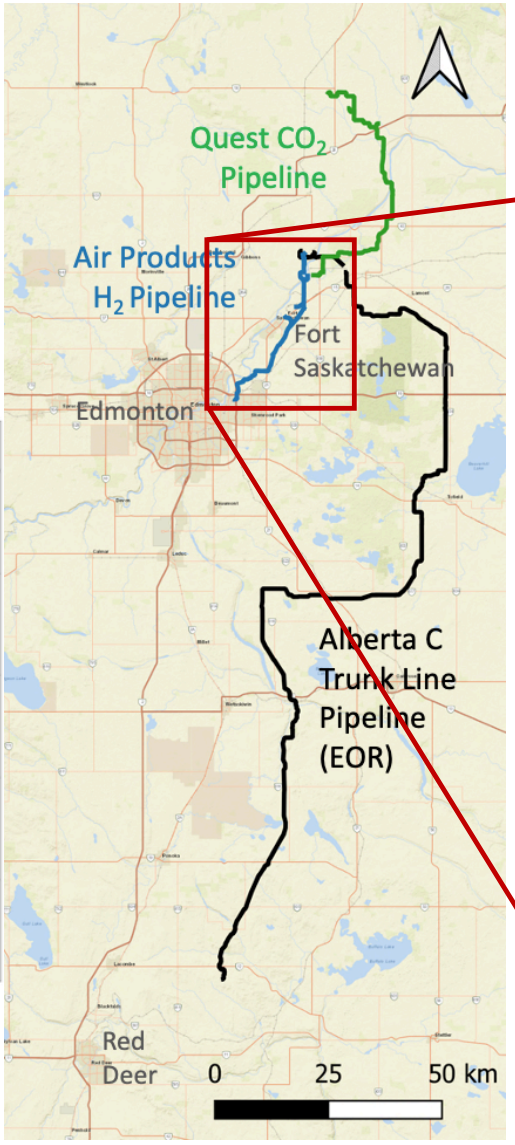
- ❑ Low-cost waste, blue or green $H_2$;
- ❑ Substantial nearby markets for the $H_2$ (esp. transport and heating fuel markets)
- ❑ Ability to connect the two (ideally pipelines);
- ❑ Scale of supply/demand where the economics works without sustained public investment;
- ❑ Engaged industry, governments and academics

*The optimal strategy varies with region of Canada:*

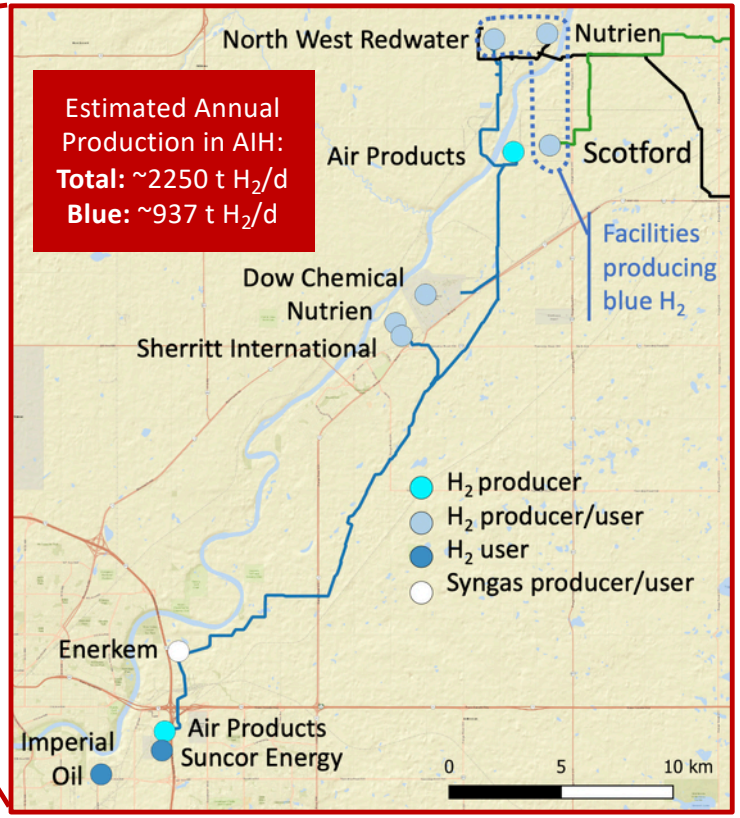
***There must be a focus on Hydrogen Hubs!***

# Alberta Makes a Lot of Hydrogen




## The Alberta Industrial Heartland (AIH)

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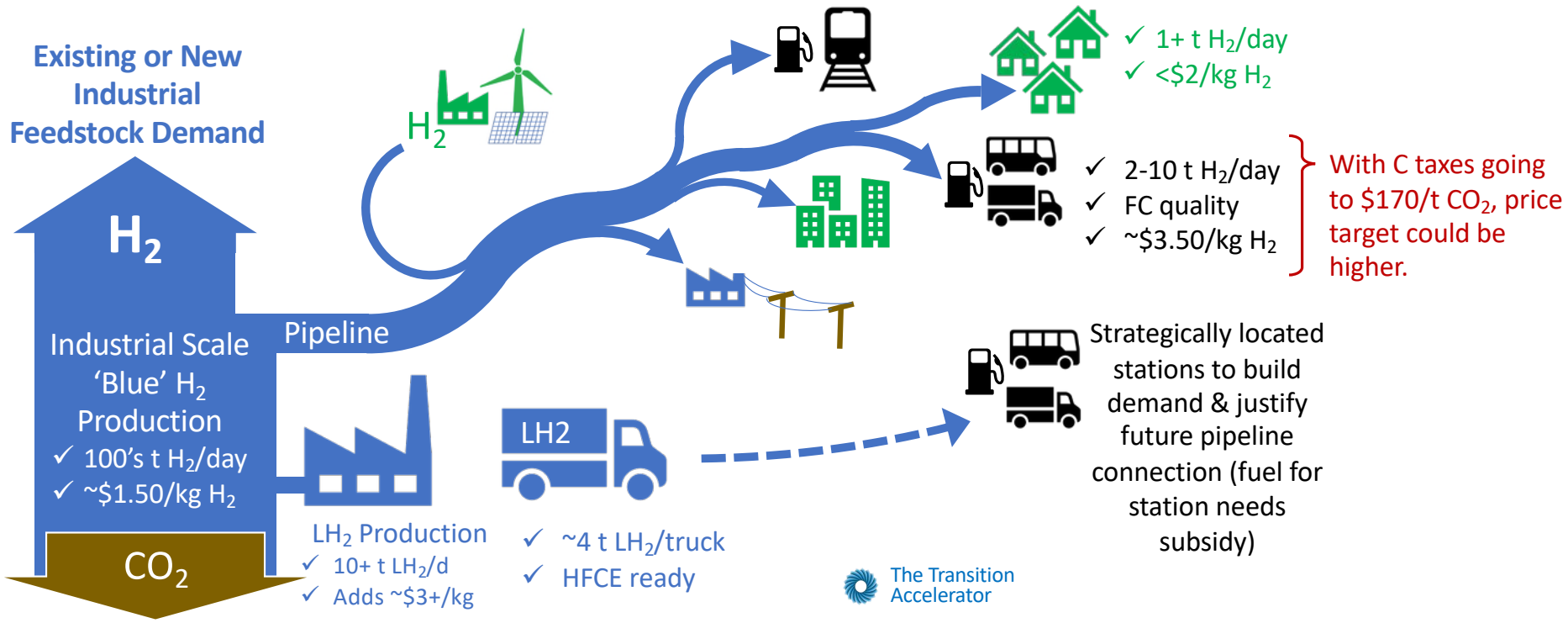
# Towards a 'Hydrogen in the Edmonton Region' (HYER) Hub

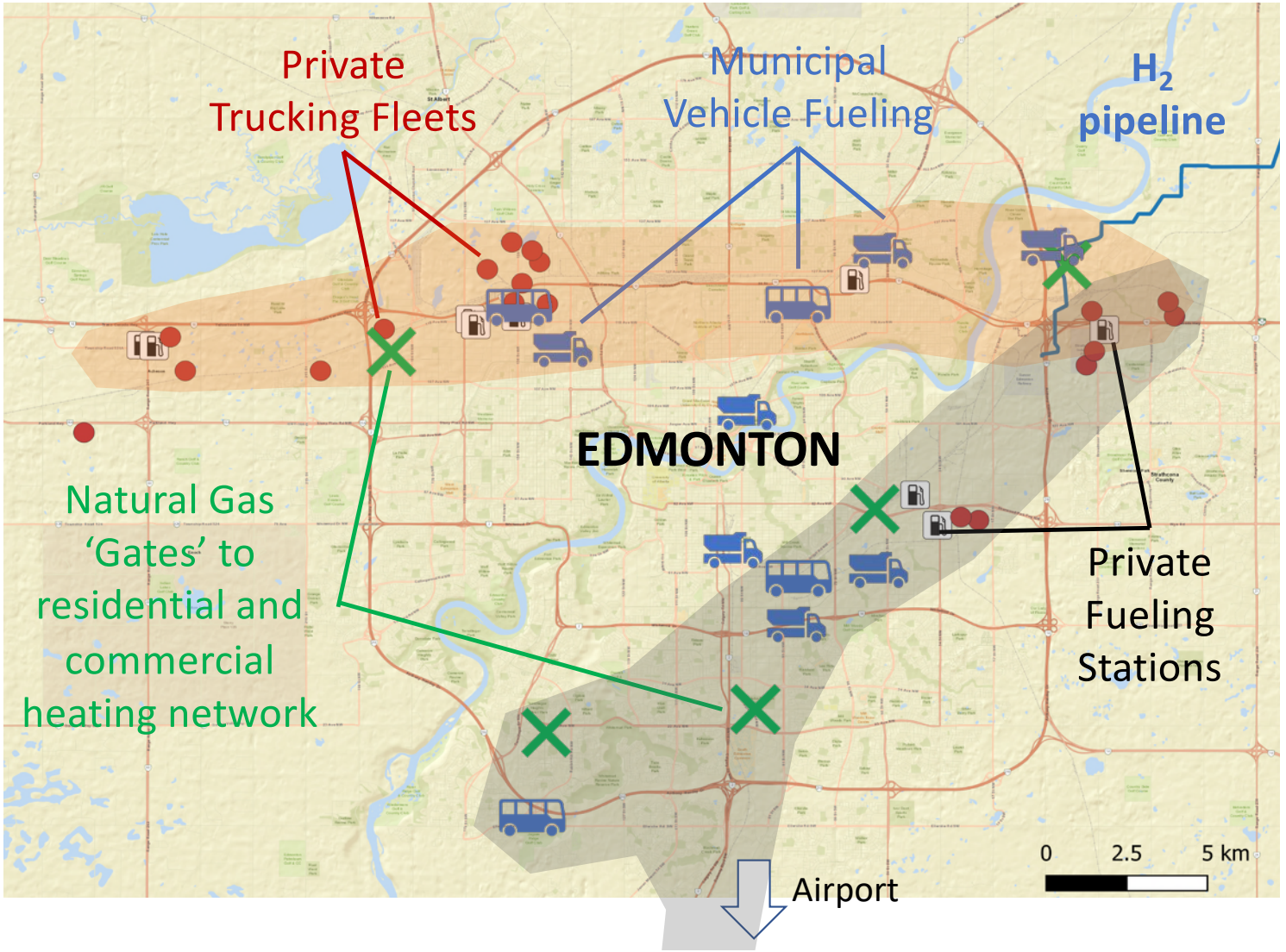



1. 'Piggy-back' on low cost industrial blue $H_2$ production.
2. Pipeline $H_2$ to new fuel markets
3. Rapidly grow $H_2$ demand
4. Attract $H_2$-using industries & OEMs

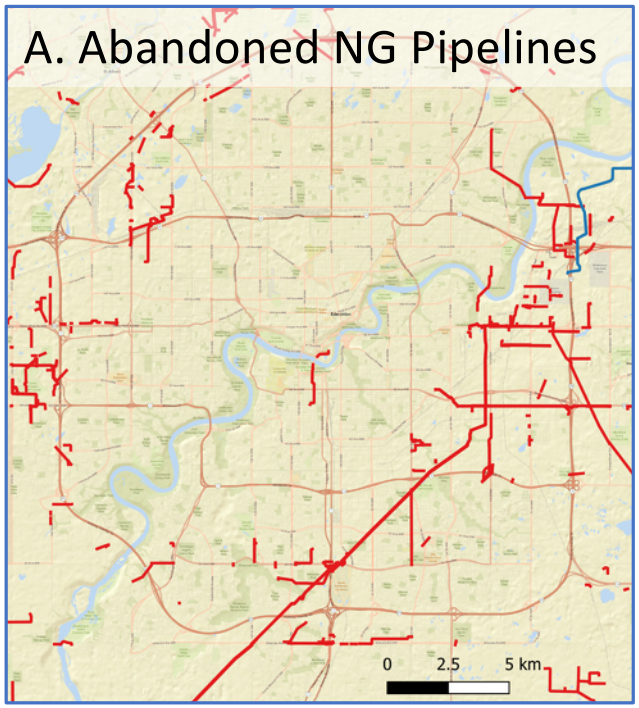
# Edmonton's Markets for Fuel Hydrogen

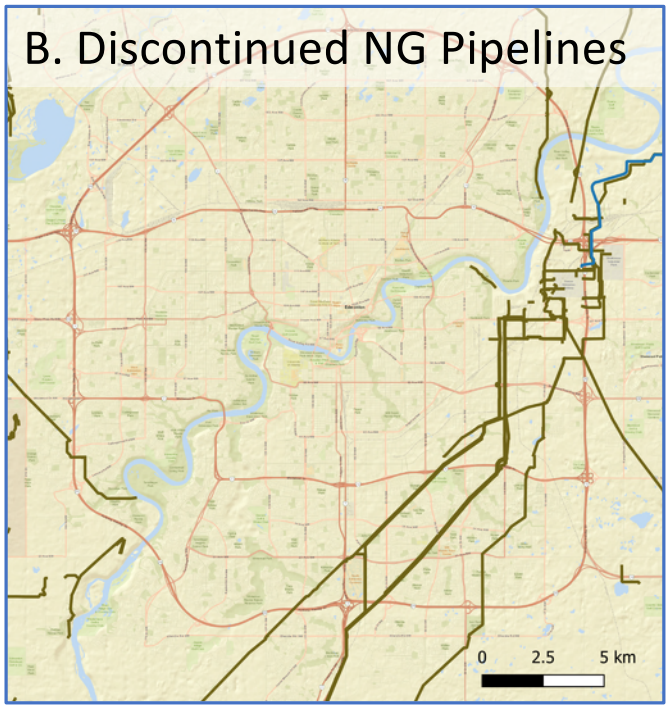
…on two corridors

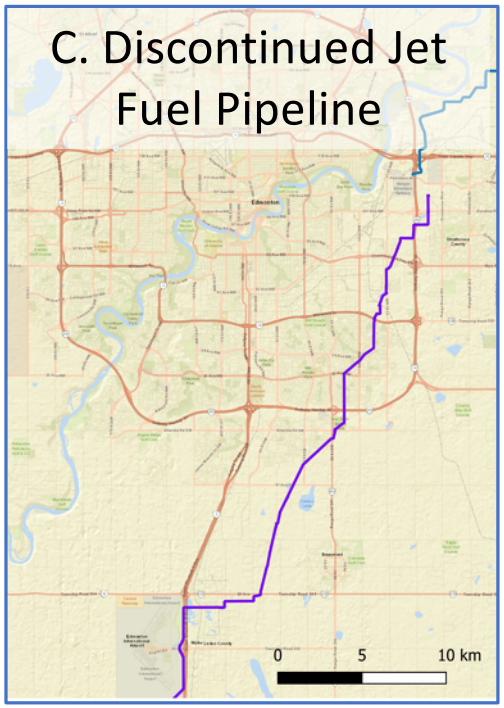
**Transportation:**
~670 t $H_2$/d
**Building Heating:**
~1500 t $H_2$/day
**+ Export**



# There may also be Discontinued Pipelines that Could be Repurposed to Carry Hydrogen



# Initial Pilots to Engage Vehicle OEMs & Operators


AMTA Alberta Motor Transport Association — LEAD BY

AZETEC
ALBERTA ZERO-EMISSION TRUCK ELECTRIFICATION COLLABORATION



BALLARD · DANA · FREIGHTLINER · nordresa · CESAR CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH · HTEC

Natural Resources Canada / Ressources naturelles Canada — Canada

EMISSIONS REDUCTION ALBERTA

- ❑ Two HFCE HD (63.5 $t_{gross}$) vehicles
- ❑ Edmonton → Calgary return;
- ❑ 700 km between refueling
- ❑ Road trials: Nov. '21- Mar '23

## HFCE Municipal Bus Fleet Project


## $H_2$-Diesel dual-fuel Project

hydra

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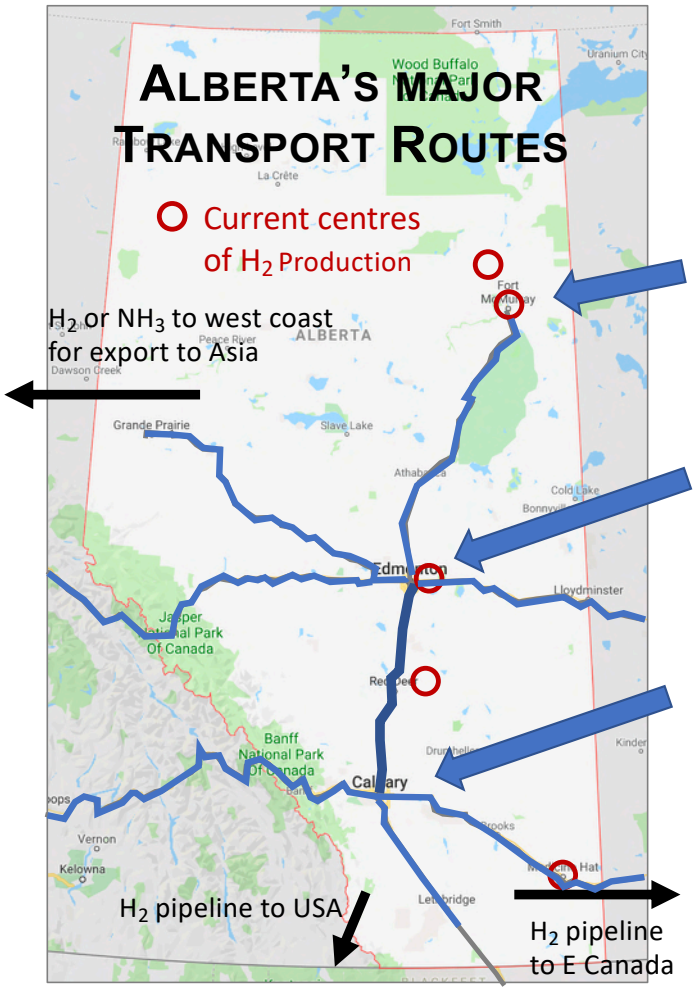
- ❑ Retrofit of diesel vehicles to take ~40% of energy from $H_2$;
- ❑ Important 'bridge' technology;
- ❑ Valuable in creating fueling station demand for $H_2$.

## $H_2$ Train Project

# Goal: Create Corridors for H2 Production & Demand




- ❑ Attract investment
- ❑ Create Jobs
- ❑ Attract OEM companies
- ❑ Reduce GHGs
- ❑ Reduce C intensity of SCO production
- ❑ Create potential for $H_2$ exports
- ❑ Alberta leads the transition to net-zero
- ❑ Create new export markets …

**Fort McMurray/ Fort McKay $H_2$ Node**

**Greater Edmonton Region $H_2$ Node**

**Greater Calgary $H_2$ Node**

**Export Markets**

Similar hydrogen node models can be deployed across Canada

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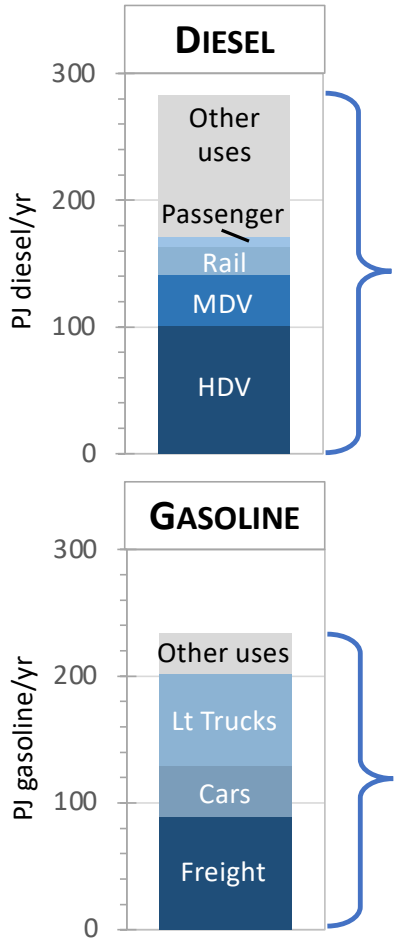
# Magnitude of the Opportunity (Challenge?) for Hydrogen to Help Canada Achieve Its Paris-2030 Commitment

*(30% Reduction in GHG Emissions by 2030)*

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

# A. Alberta Transportation Fuel Market: 30% reduction by 2030

**ALBERTA (2017)**




| | % TO $H_2$ | DRIVE TRAIN EFFICIENCY (J $H_2$/J DIESEL) | $H_2$ DEMAND (PJ $H_2$/YR) |
|---|---|---|---|
| DIESEL | 35% | 0.86 | 85 |
| GASOLINE | 5% | 0.56 | 0.9 |

## IMPLICATIONS BY 2030…

### Blue $H_2$ production

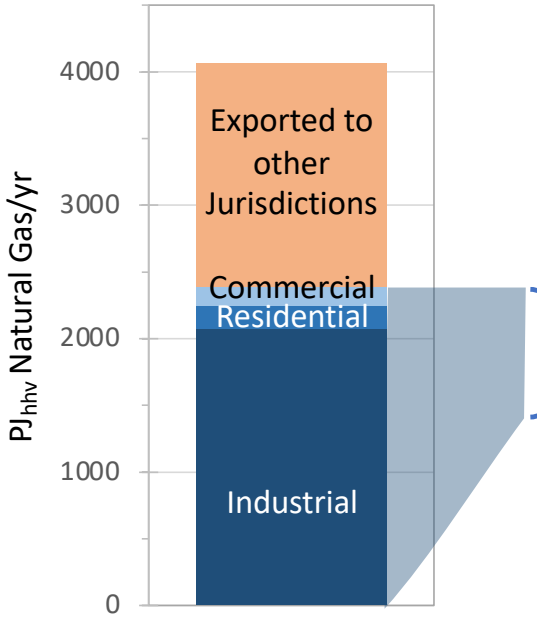
- ❑ 1,668 t $H_2$/d
- ❑ 31% incr. in AB $H_2$ production
- ❑ ~4 new 400 t $H_2$/d SMR or ATR
- ❑ CCS: 5 Mt $CO_2$/yr
- ❑ WTW GHG red'n: 9.5 Mt $CO_2$/yr
- ❑ 30% reduction in fuel GHGs

### Fueling Stations/Vehicles

- ❑ 167 stations @ 10t $H_2$/d/station
- ❑ Serving ~111,000 vehicles using average of 15 kg $H_2$/veh/day
- ❑ <3.4% of registered vehicles in AB would convert to either:
  - ➢ $H_2$-diesel dual fuel or
  - ➢ $H_2$ fuel cell electric

# B. NG Decarbonization for Use in Alberta (~2%)

**ALBERTA (2018) NG PRODUCTION**




**FRACTION FOR DECARBON-IZATION** (PJ NG/YR)

1000

**$H_2$ BLENDING**

- ❑ 15% of volume
- ❑ 5.23% of energy

**$H_2$ DEMAND** (PJ $H_2$/YR)

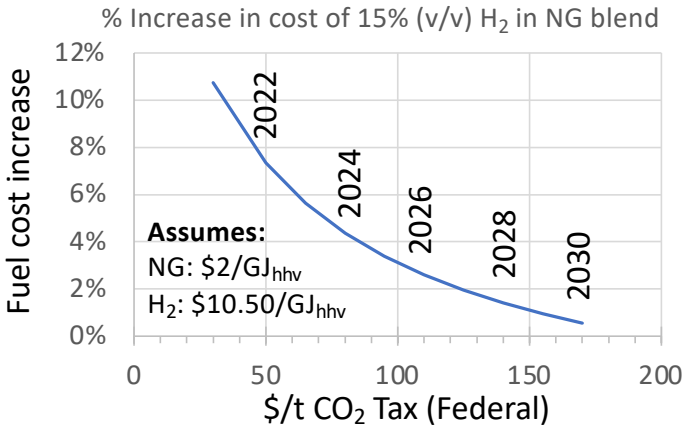
52.3

***NOTE:*** *The $H_2$ infrastructure (pipelines) needed for fueling stations could also support NG decarbonization and 'buffer' fueling station demand.*

## IMPLICATIONS BY 2030…

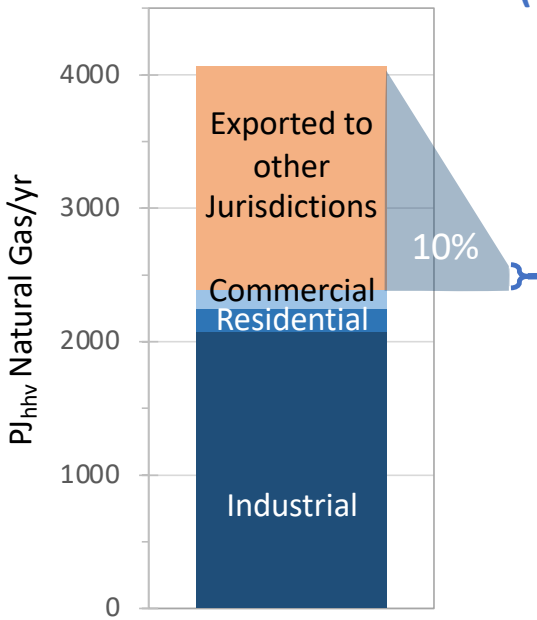
### Blue $H_2$ production

- ❑ 1011 t $H_2$/d
- ❑ 19% incr. in AB $H_2$ production
- ❑ 2-3 new 400 t $H_2$/d SMR or ATR
- ❑ CCS: 3.2 Mt $CO_2$/yr
- ❑ LC GHG red'n: 2.1 Mt $CO_2$/yr



# C. Export by Pipeline

**ALBERTA (2018) NG PRODUCTION**




**POTENTIAL NEW NA FUEL MARKETS FOR HYDROGEN (E.G. DIESEL ALTERNATIVE)**
(PJ $H_2$/YR)

167

OR

California wants Green Hydrogen

## IMPLICATIONS BY 2030…

**Blue $H_2$ production**

- 3237 t $H_2$/d
- 60% incr. in AB $H_2$ production
- 8 new 400 t $H_2$/d SMR or ATR
- CCS: 10 Mt $CO_2$/yr

**Green $H_2$ production:** From dedicated wind → $H_2$ (@ 38% CF):

- 3237 t $H_2$/d
- 18.4 GW new wind generation
- 11X current wind capacity in AB
- ~3100 large (6 MW) wind turbines, dedicated to $H_2$ prod'n
- Require ~11 $Mm^3$ water/yr (<10% of water use in Calgary)

# Exporting by Ship: As Ammonia to Japan

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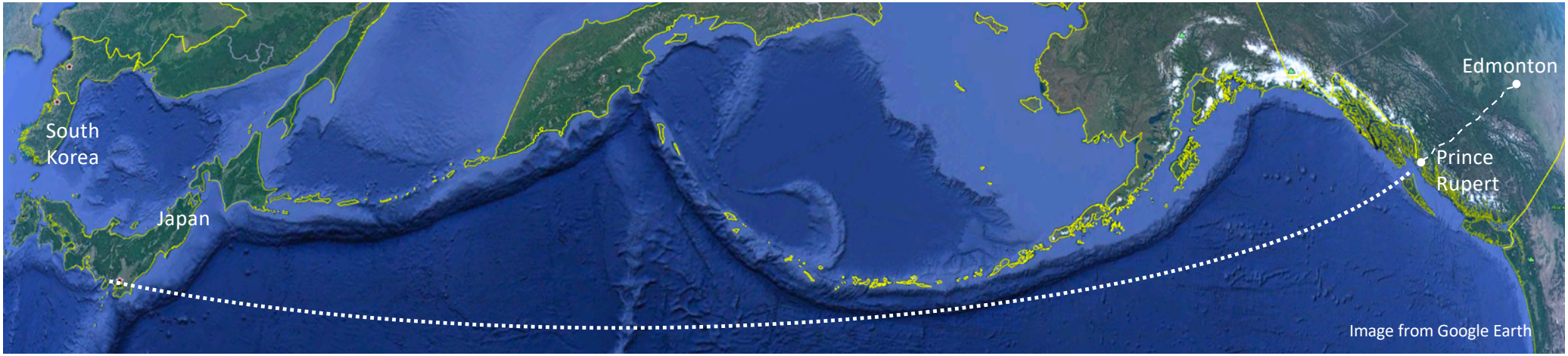


Japan's 2030 Import Target:
**300,000 t $H_2$/yr**
Energy equivalence:
**1.94 Mt Ammonia ($NH_3$)/yr**
*(easier to transport, esp. long distances)*

Assume 50% from Canada

Saudi Arabia, Australia, etc?

## Implications by 2030…

- 968 kt $NH_3$/yr
- ~411 t $H_2$/day
- ~1 new large $NH_3$ facility
- CCS: 1.4 Mt $CO_2$/yr

*$NH_3$ can be used directly as a C free fuel, or converted back to $H_2$*

## Option 1: Rail Blue $NH_3$ to Coast

- 110 t $NH_3$/rail car
- 100 cars/unit train
- 88 unit trains/yr
- ~1 train every 4 days

## Option 2: Pipeline Blue $H_2$, make $NH_3$ at coast


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