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Hydrogen and the Transition to Net-Zero Energy Systems

The Canadian Academy of Engineering
L'Académie canadienne du génie

Presentation to the Fellows
Nov. 23, 2021

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Net-Zero Emissions by 2050

...Committed to by Canada, USA and dozens of other Countries

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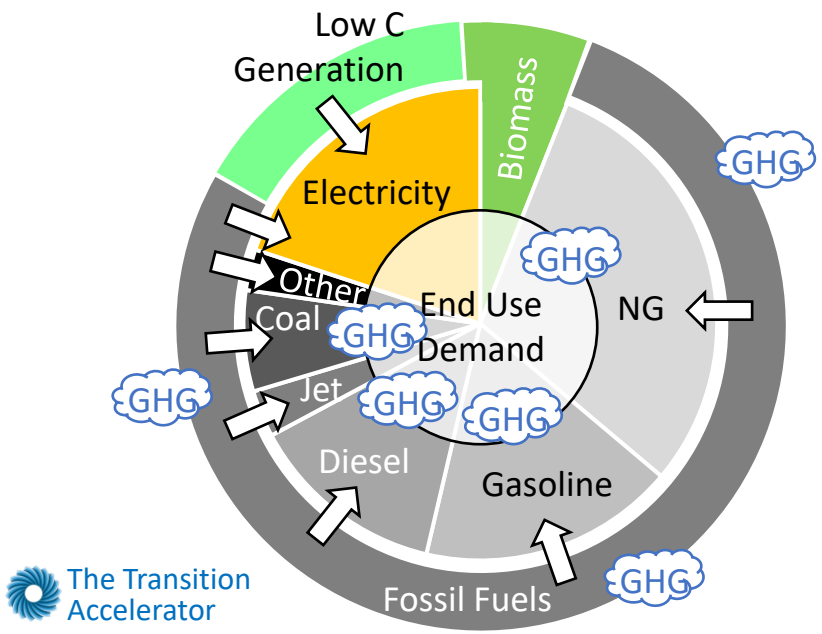
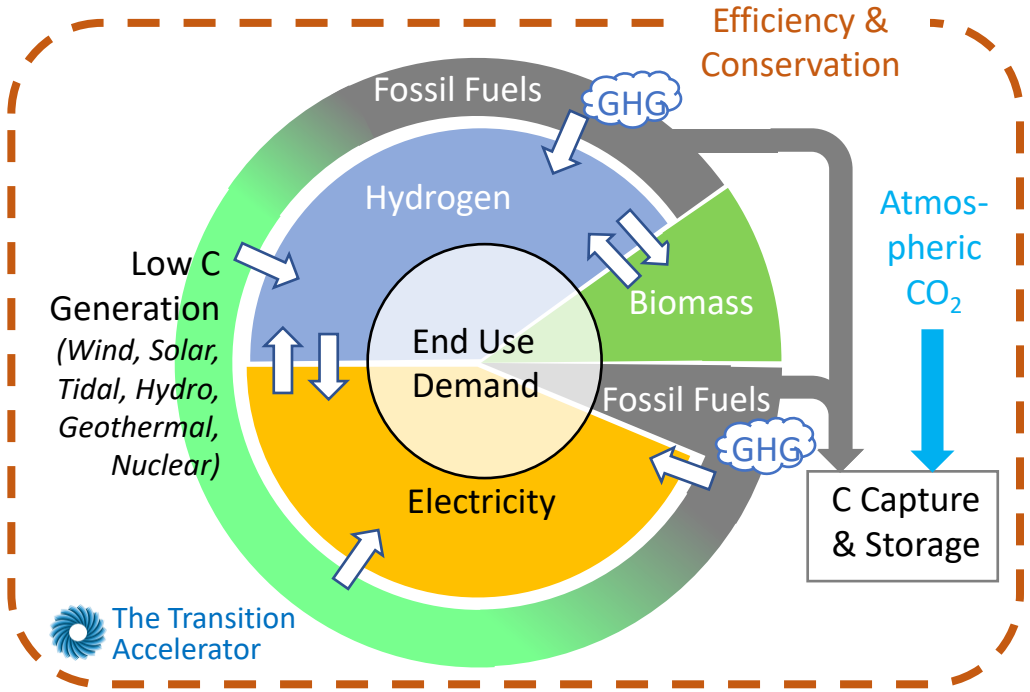
- *How can Canada 'win'?*
- *What are the best transition pathways?*

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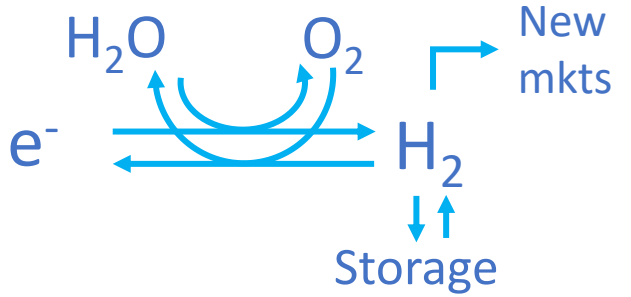
- *How can Canada 'win'?*
- *What are the best transition pathways?*

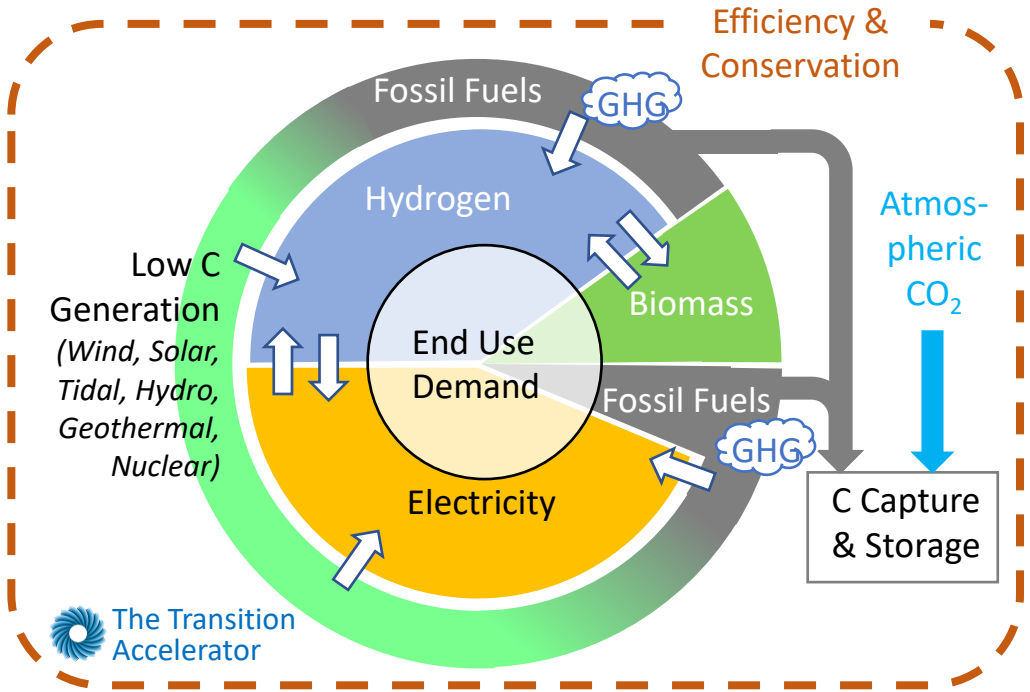
Why Hydrogen (H_2)?

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**

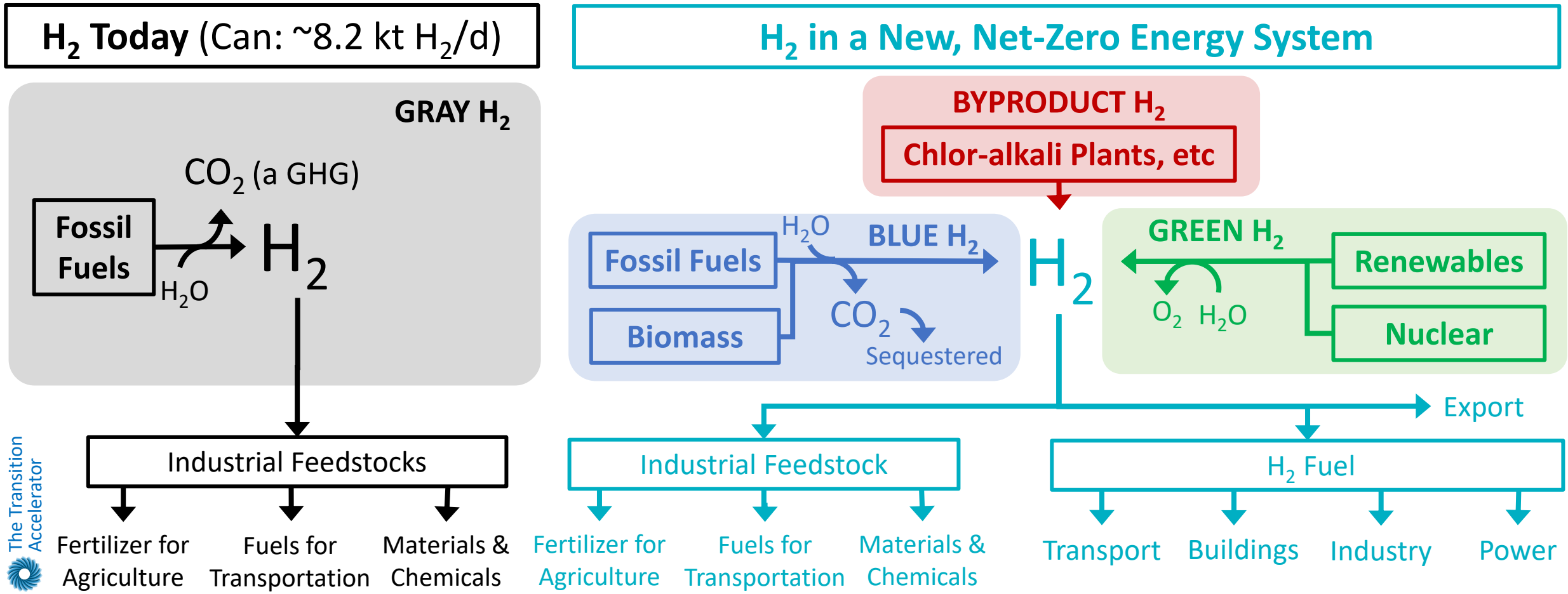


3. **Enhances biofuel production**

Net-Zero Energy System



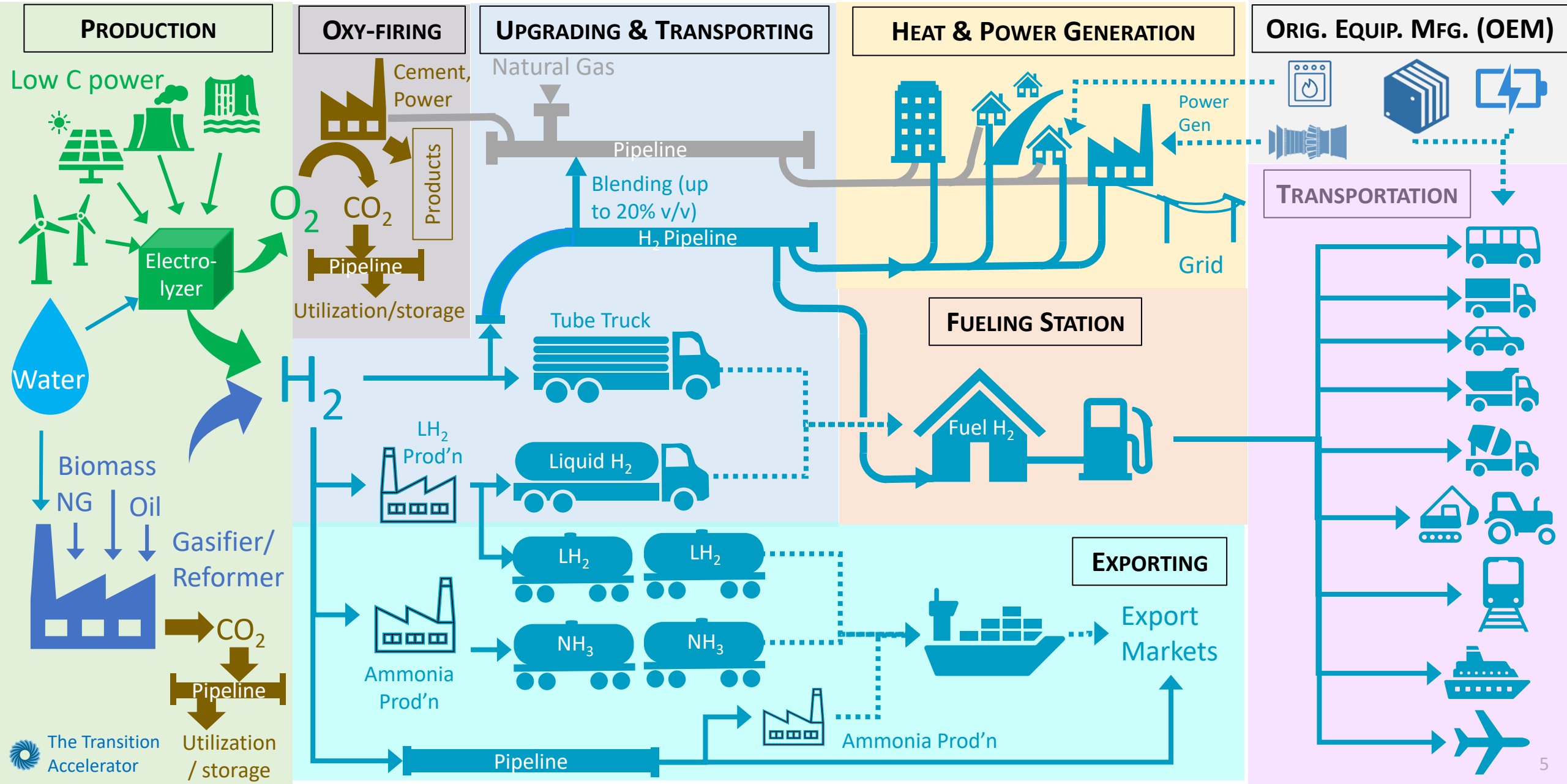
Towards a New Hydrogen (H_2) Economy



The Transition Accelerator

from Layzell et al. 2020

What are the Value Chains in a New Hydrogen Economy?

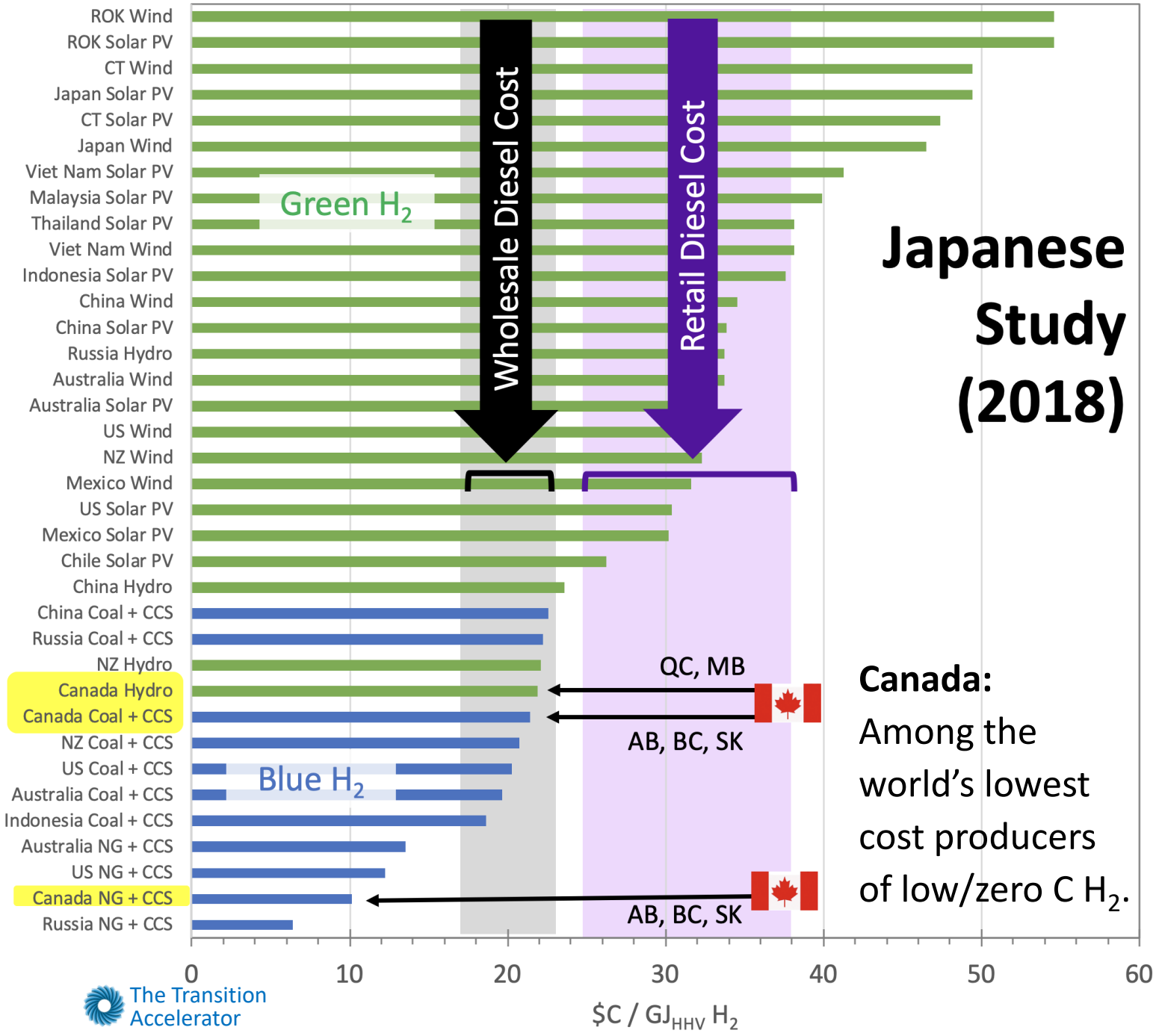


The Transition Accelerator

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)



Japanese Study (2018)

Canada: Among the world's lowest cost producers of low/zero C H_2.

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

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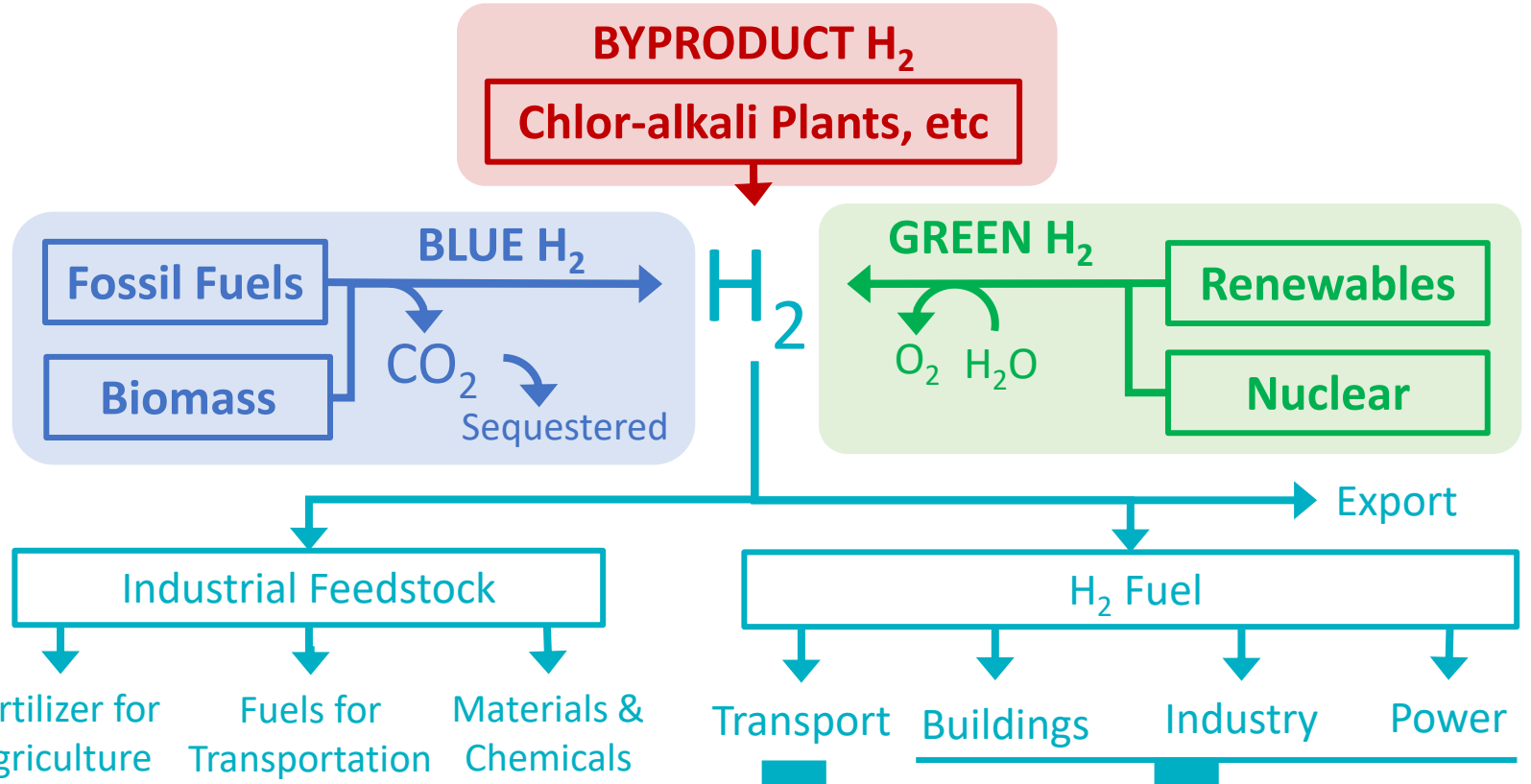
Canada has low-cost Blue & Green H_2…
But what about the environmental footprint?

Life Cycle GHG Intensity

~3

$\frac{kg\ CO_2e}{kg\ H_2}$

Assumes upstream CH_4 emissions (as CO_2e) = 19% of combustion emissions. This must be reduced!



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Reduction in Life cycle C Emissions

80% to 95%

67% to 90%

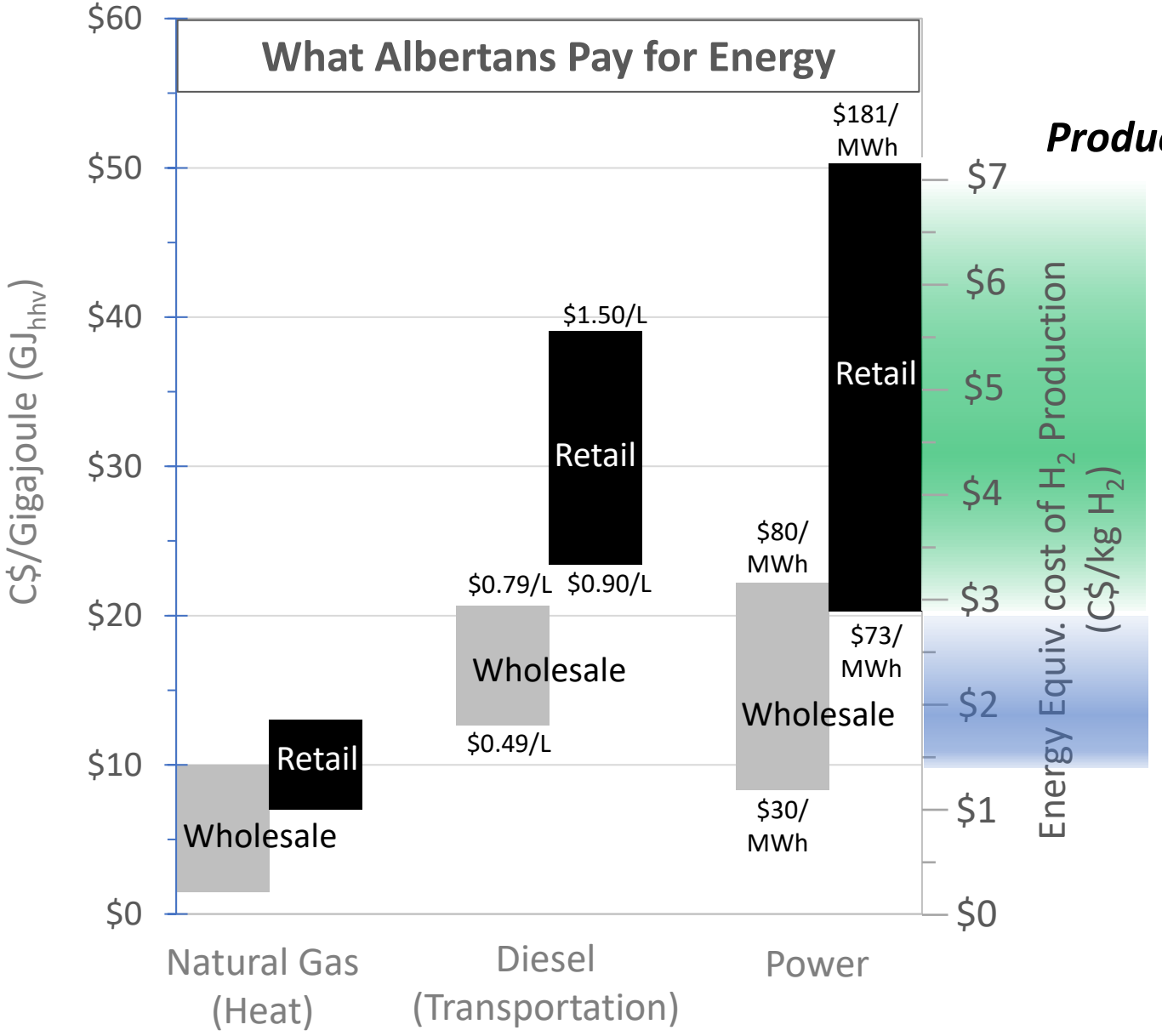
Life Cycle GHG Intensity

~0.8 to 3

$\frac{kg\ CO_2e}{kg\ H_2}$

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

What Markets for Hydrogen are Most Promising?…



Green H_2
(Costs expected to decline to ~$2/kg by 2030 @ <$20/MWh_e)

Blue H_2
(Lower costs @ larger scales)

Heavy Transportation:

Offers the market where H_2 is most likely to be **economically viable** in the short to medium term.

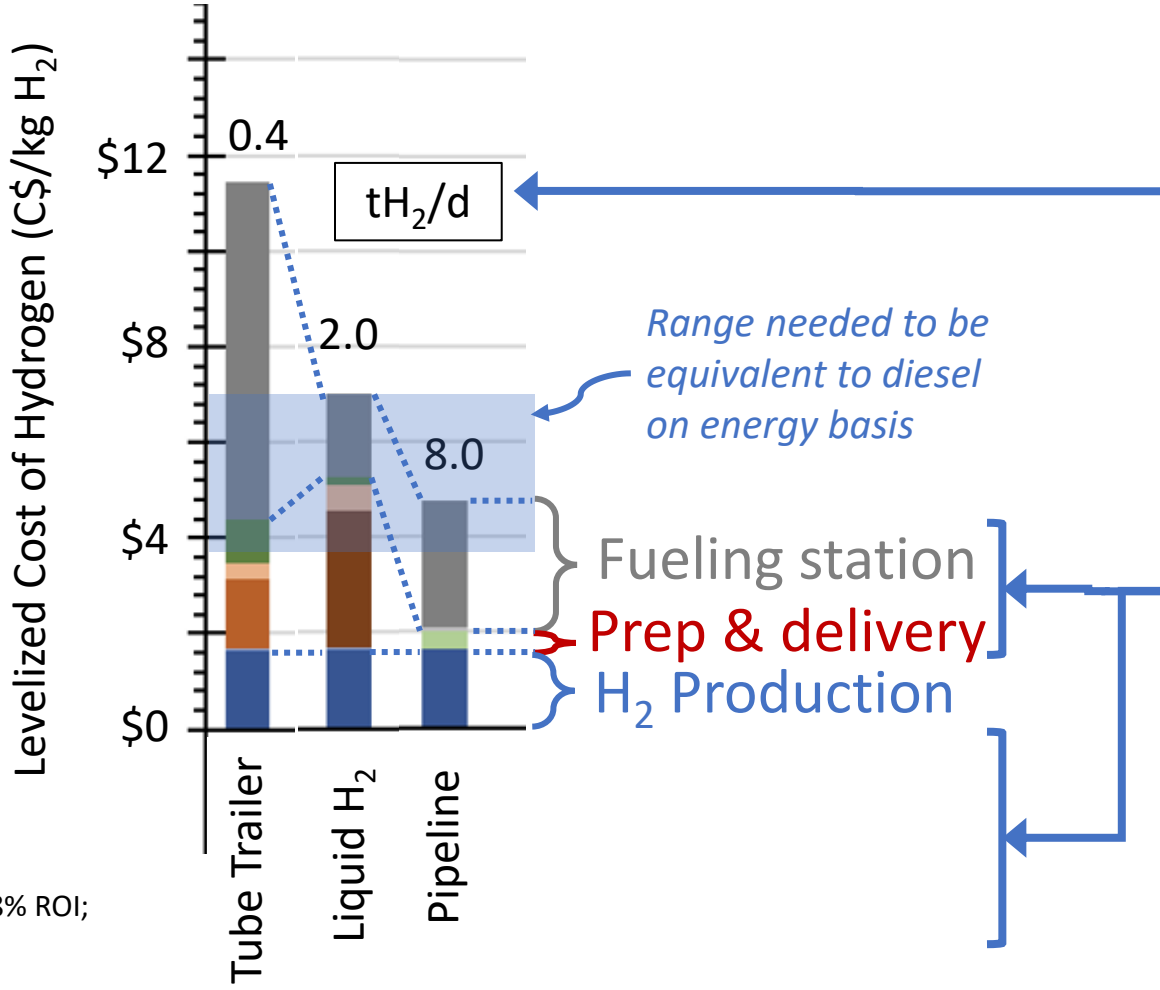
More Challenging:

- ❑ 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 H_2 as a Transportation Fuel

Retail Cost Estimates for H_2 Fueling Station within 5 km of Supply



Assumes 8% ROI; $2/GJ NG

Lowest cost delivery @ scale

NOTE:

1. Fueling station size has a major impact on the retail cost of delivered H_2:
   - To be economically sustainable, 2+ t H_2/d is needed.
   - =~80+ buses/stn. OR ~40 class 8 trucks/stn

2. While H_2 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 H_2 Problem…

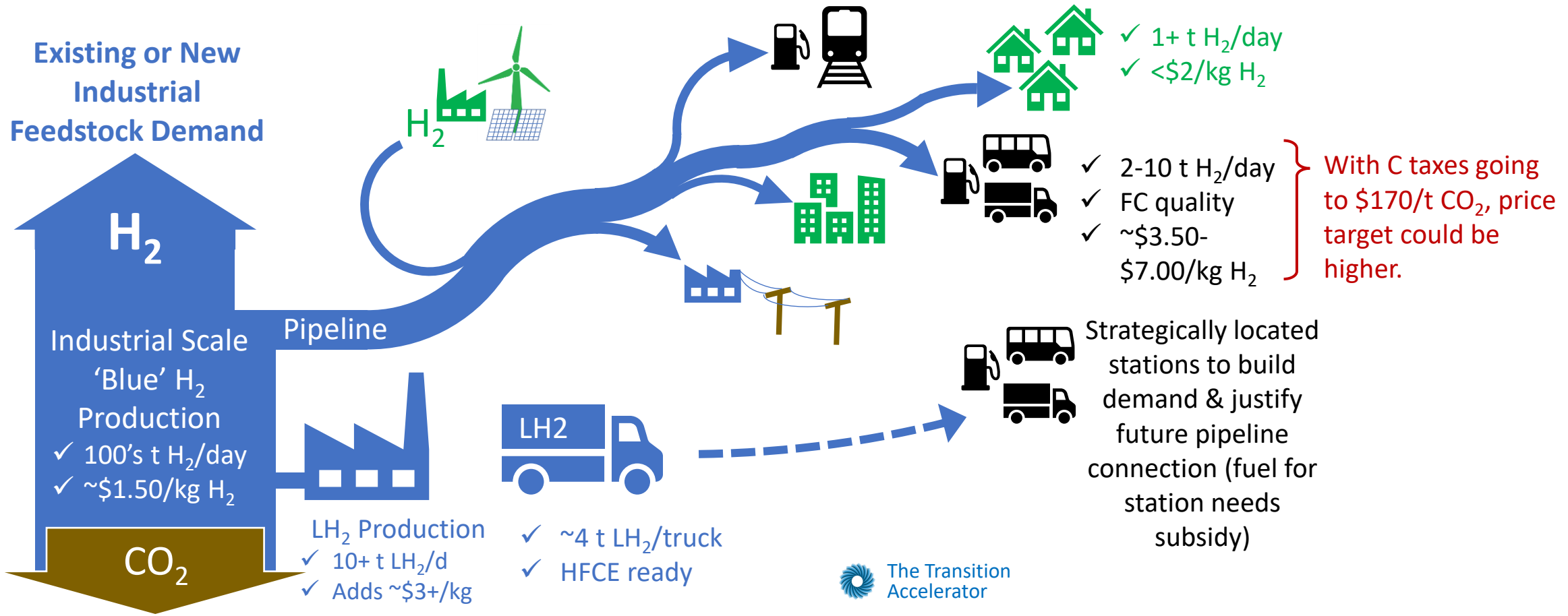
Its a gas, therefore more difficult to move and store than liquids, especially in small quantities.

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
- ✓ 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 H_2 Value Chain in Alberta

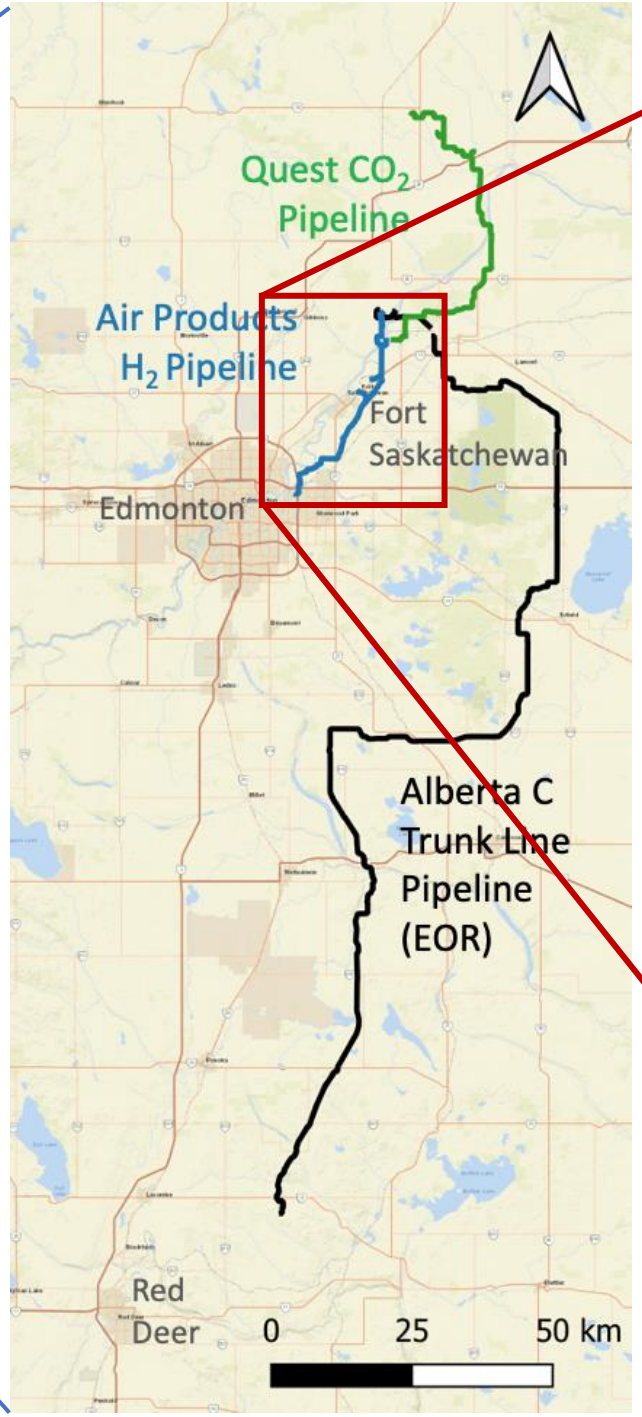


1. 'Piggy-back' on low cost industrial blue H_2 production.
2. Pipeline H_2 to new fuel markets
3. Rapidly grow H_2 demand
4. Attract H_2-using industries & OEMs

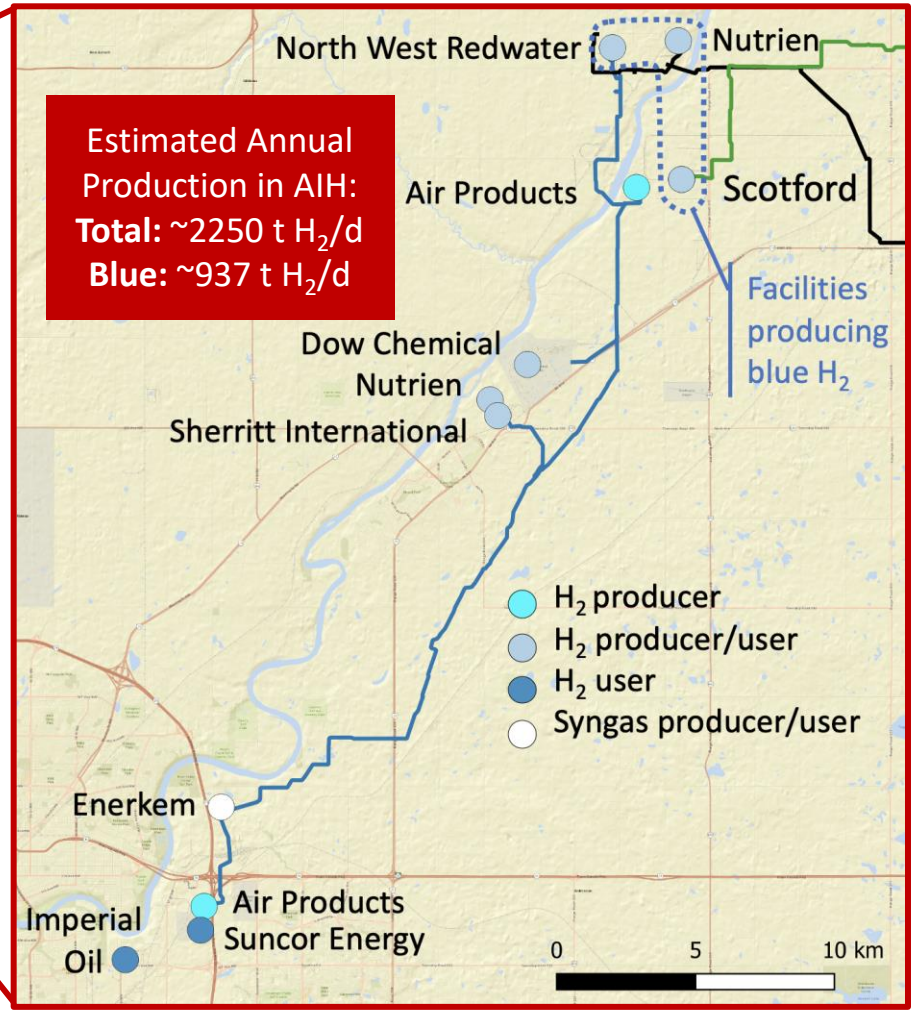
Hydrogen in Alberta

Alberta currently produces:

- ❑ ~5,400 t H_2/day
- ❑ 2/3rd of Canadian production
- ❑ For use as industrial feedstock
  - ✓ Fertilizer production
  - ✓ Oil upgrading/refining
  - ✓ Chem & material production



The Alberta Industrial Heartland (AIH)



New Blue H_2 initiatives

May 2021: Suncor/ATCO for ~2027
June 2021: Air Products for ~2024
July 2021: Scotford CO_2 infrastructure
Aug 2021: Petronas-Itochu H_2/NH_3 export
Sept 2021: Mitsubishi-Shell Canada H_2/NH_3
Nov. 2021: Northern Petrochem. Corp. H_2/NH_3

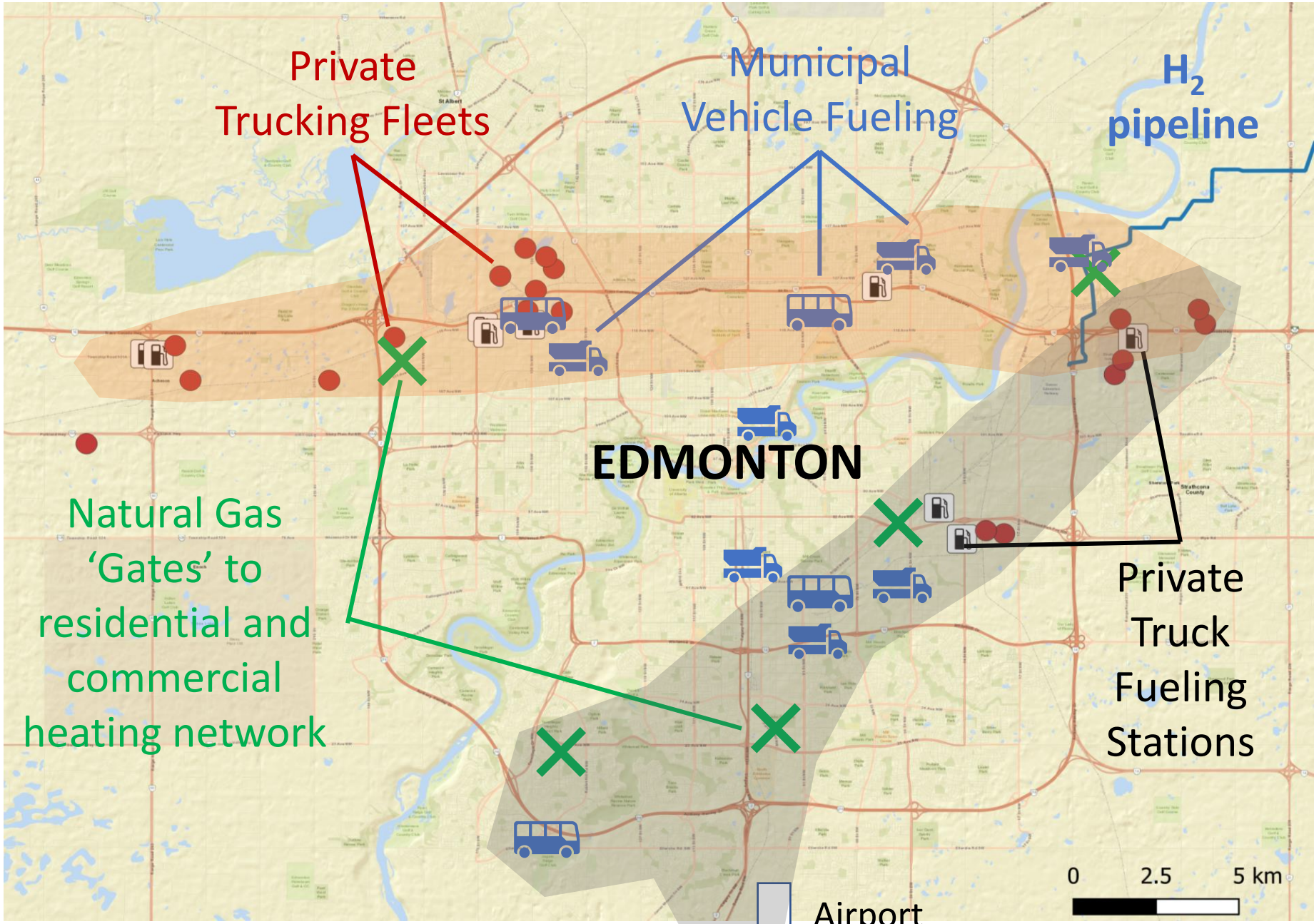
EDMONTON REGION Hydrogen HUB

EDMONTON REGION
Hydrogen HUB

Edmonton's Markets for Fuel Hydrogen

...on two corridors

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



Power & Control in the New H_2 Value Chain

4. Fuel Supply

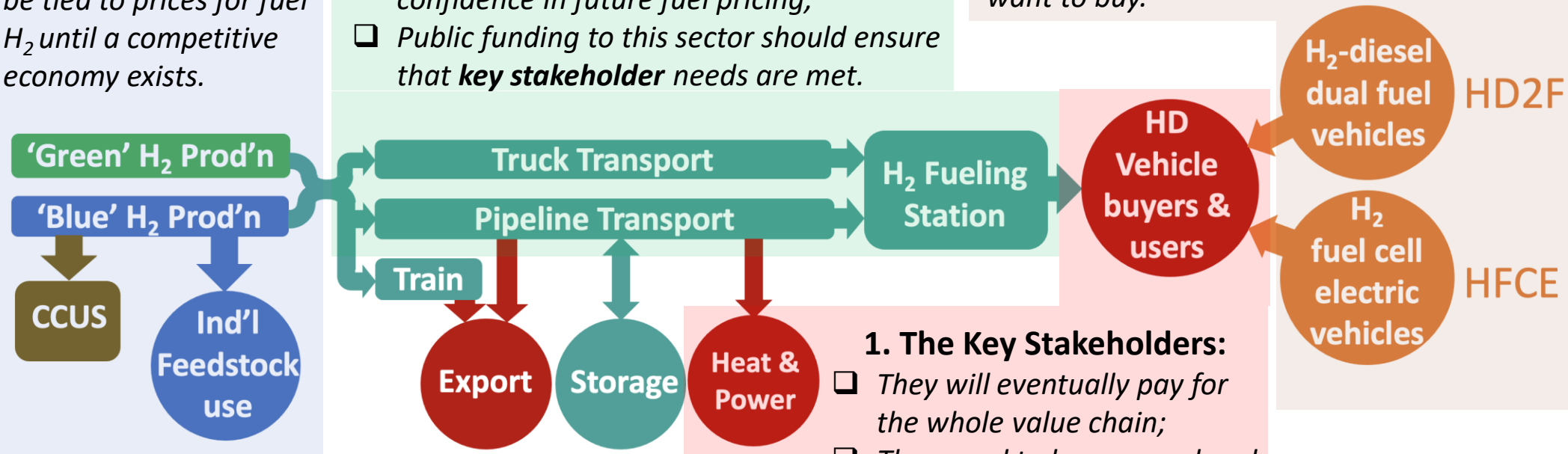
- ❑ *Many companies want to provide fuel H_2 – highly competitive;*
- ❑ *Public subsidies need to be tied to prices for fuel H_2 until a competitive economy exists.*

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]*

EDMONTON REGION Hydrogen HUB

EDMONTON REGION Hydrogen HUB

Projects being Deployed

AZETEC

ALBERTA ZERO-EMISSION TRUCK ELECTRIFICATION COLLABORATION

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

AMTA Alberta Motor Transport Association

EMISSIONS REDUCTION ALBERTA

AZEHT

ALBERTA ZERO-EMISSION HYDROGEN TRAN

ETS

Calgary Transit

STRATHCONA COUNTY

Roam

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

EMISSIONS REDUCTION ALBERTA

CP

HYDROGEN-POWERED LINE-HAUL FREIGHT LOCOMOTIVE

EMISSIONS REDUCTION ALBERTA

- ❑ Converting three diesel-electric locomotives to hydrogen fuel cell-electric locomotives
- ❑ Two hydrogen fueling stations
- ❑ ETA: 2022

H_2-DIESEL DUAL FUEL TECHNOLOGY

- ❑ Multiple projects to develop and deploy HD2F on HD trucks;
- ❑ Important 'bridge' technology to creating fueling station demand for H_2.
- ❑ ETA (Hydra Energy): 2022

ULEMCo

ultra low emission mileage company limited

hydra

UNIVERSITY OF ALBERTA
QUAECUMQUE VERA

Koch lab.

Cummins

NORTH AMERICAN CONSTRUCTION GROUP

EDMONTON REGION Hydrogen HUB

AMTA Alberta Motor Transport Association

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:

- H_2-diesel dual fuel:
- H_2 Fuel cell electric

SUNCOR ENERGY

AMTA Alberta Motor Transport Association

Natural Resources Canada / Ressources naturelles Canada

Canada

HYDROGEN FUELING STATIONS

- To support AZETEC, AZEHT and HD2F pilots and Demonstration Projects
- ETA: 2022

METHANE PYROLYSIS PROJECTS

- Various proponents & funders
- Various Funding Agencies
- Would allow 'blue' H_2 to be created anywhere there is natural gas,
- No CCS needed!

$$CH_4 \rightarrow 2H_2 + C$$

Natural Gas

Carbon Black

- Rubber tires
- Paints
- ...?

ATCO

FORT SASKATCHEWAN HYDROGEN BLENDING PROJECT

- 5% H_2 blending into a portion of the natural gas distribution system in Fort Saskatchewan, AB

EMISSIONS REDUCTION ALBERTA

Magnitude of the Opportunity

Magnitude of the Opportunity / Challenge

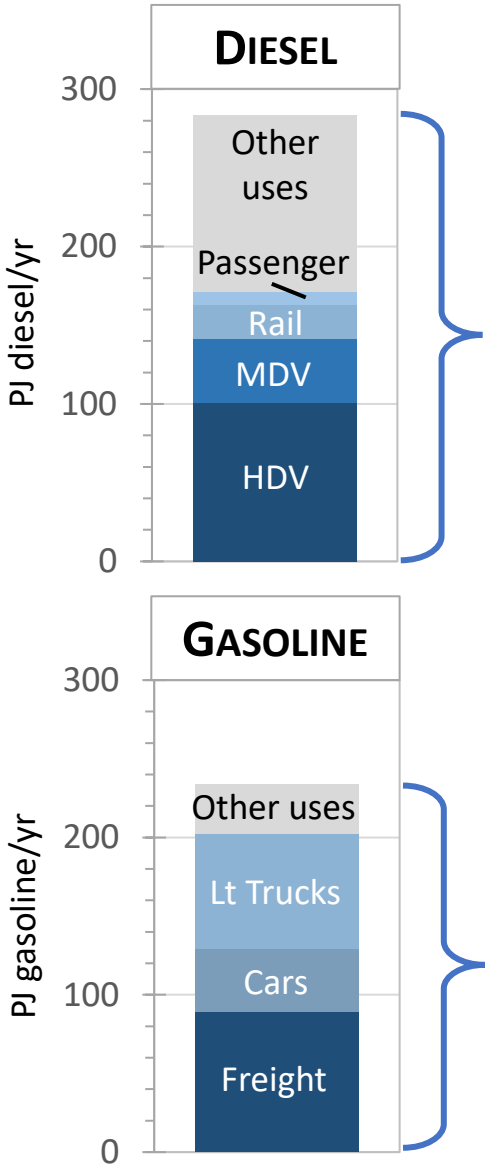
A. Alberta Transportation Fuel Market
B. Provincial Natural Gas Demand
C. Export by pipeline
D. Export by ship

Assumes

- 2018 demand
- Any increases in demand with population/GDP growth offset by efficiency / conservation

A. Alberta Transportation Fuel Market

ALBERTA (2017)



	% TO H_2	DRIVE TRAIN EFFICIENCY (J H_2/J DIESEL)	H_2 DEMAND (PJ H_2/YR)
DIESEL	80%	0.86	195
GASOLINE	20%	0.56	26
			221

IMPLICATIONS…

Blue H_2 production

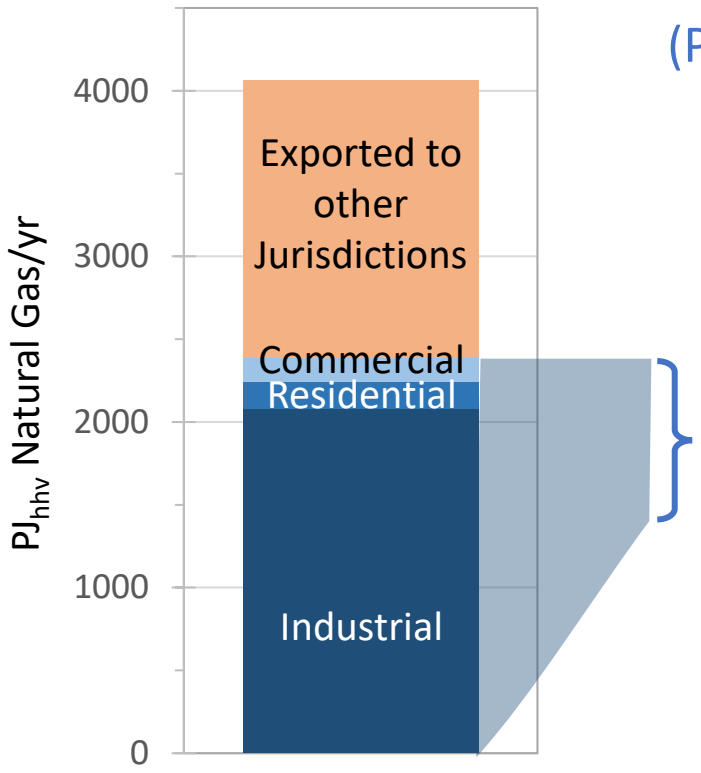
- 4277 t H_2/d
- 79% incr. in AB H_2 production
- ~11 new 400 t H_2/d SMR or ATR
- CCS: 13 Mt CO_2/yr
- WTW GHG red'n: 25 Mt CO_2/yr

Fueling Stations

- 428 stations @ 10t H_2/d/station
- Many pipeline connected

B. NG Decarbonization for Use in Alberta

ALBERTA (2018) NG PRODUCTION



MARKET FRACTION TO H_2 (PJ NG/YR)

1000

H_2 BLENDING

- ❑ Start with H_2 blending up to 20%;
- ❑ Then shift to pure H_2 with infrastructure change

H_2 DEMAND (PJ H_2/YR)

1000

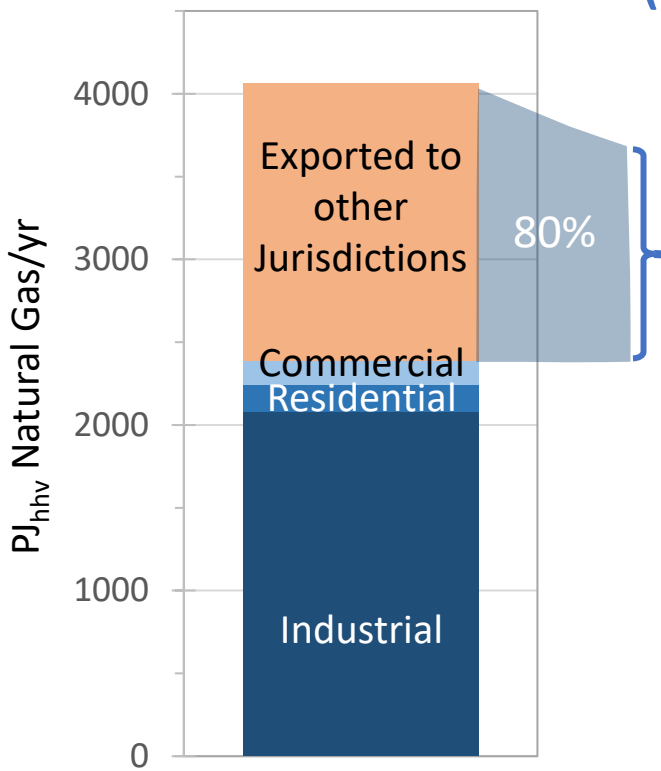
IMPLICATIONS…

Blue H_2 production

- ❑ 19,335 t H_2/d
- ❑ 358% incr. in AB H_2 production
- ❑ 48 new 400 t H_2/d SMR or ATR
- ❑ CCS: 60 Mt CO_2/yr
- ❑ LC GHG red'n: 40 Mt CO_{2e}/yr

C. Export by Pipeline

Alberta (2018) NG Production



Potential new NA fuel markets for Hydrogen (e.g. diesel alternative)

(PJ H_2/yr)

1340

OR

California wants Green Hydrogen

Implications

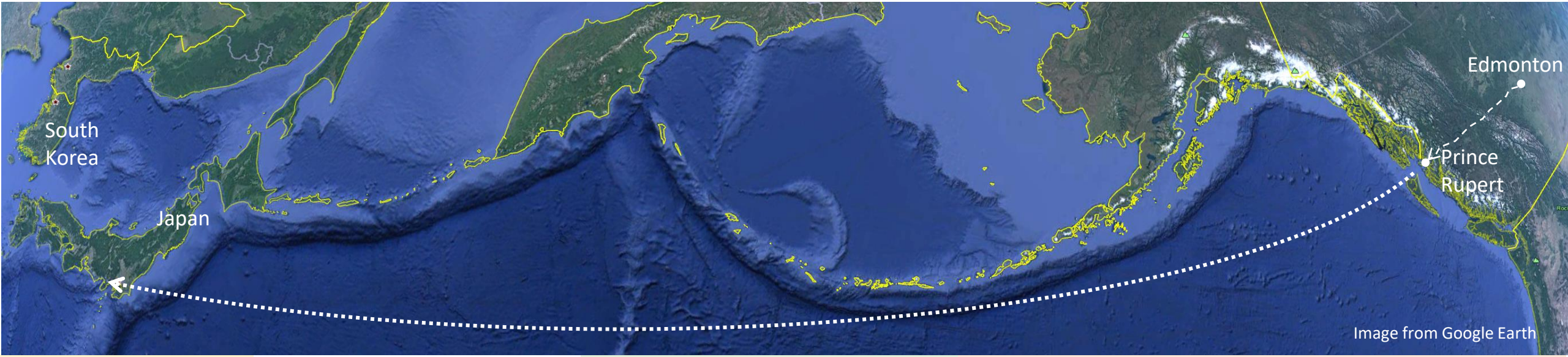
Blue H_2 production

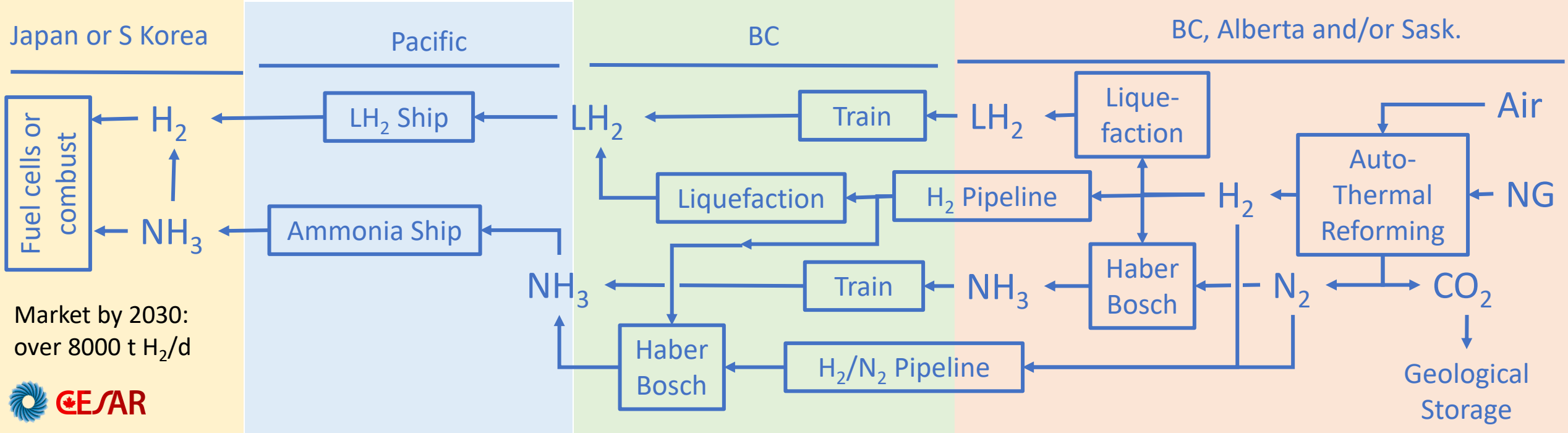
- 25,900 t H_2/d
- 480% incr. in AB H_2 production
- 65 new 400 t H_2/d SMR or ATR
- (SAGD oil sands could be also converted to blue H_2)
- CCS: 81 Mt CO_2/yr

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

- 25,900 t H_2/d
- 147 GW new wind generation
- 87X current wind gen cap in AB
- ~24,500 large (6 MW) wind turbines, dedicated to H_2 prod'n
- Require ~85 Mm^3 water/yr (<51% of water use in Calgary)

D. Moving H_2 to Asia





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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 H_2 Hubs and corridors;
- We need to start now!

Thank you!

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