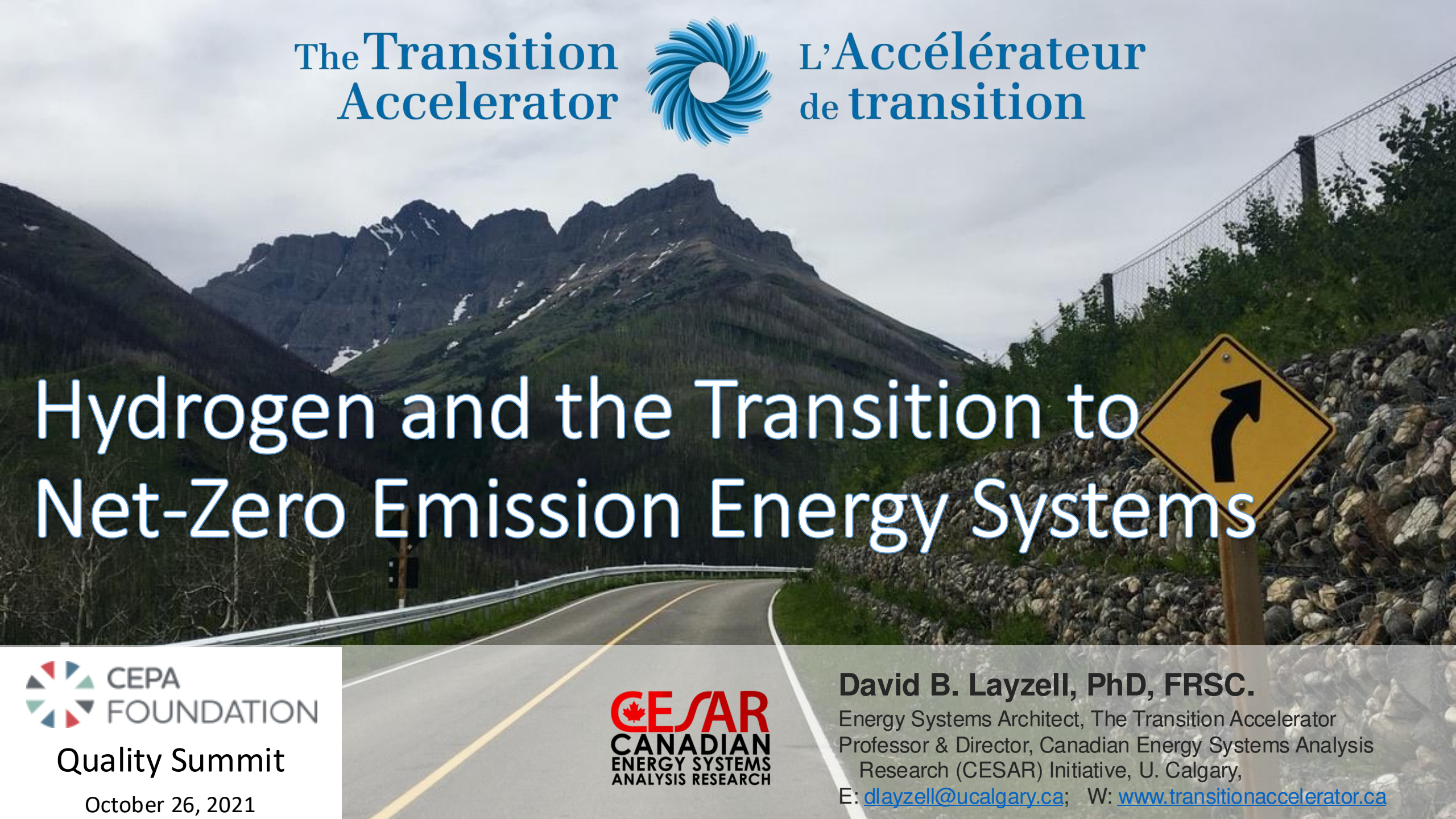

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Hydrogen and the Transition to Net-Zero Emission Energy Systems

CEPA FOUNDATION

Quality Summit

October 26, 2021

CESAR CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH

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Net-Zero Emissions by 2050

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

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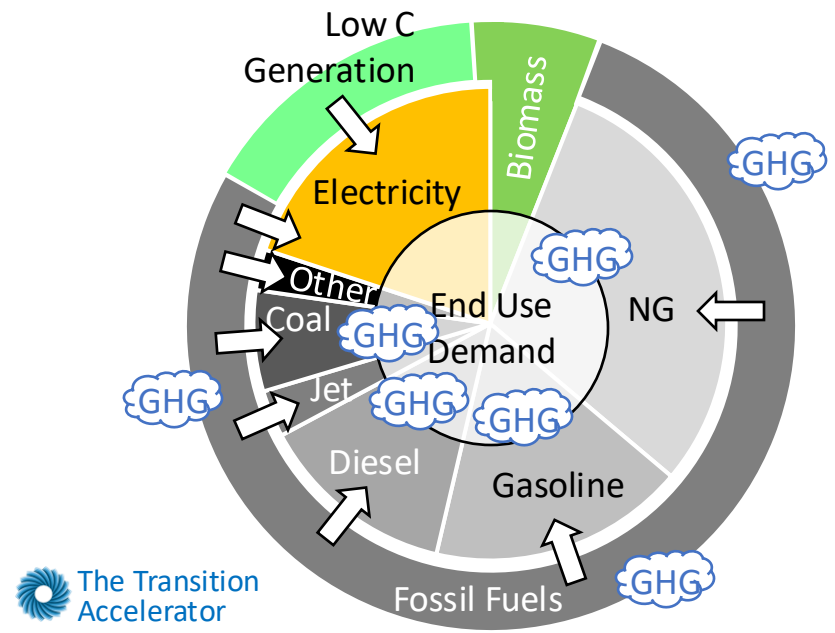
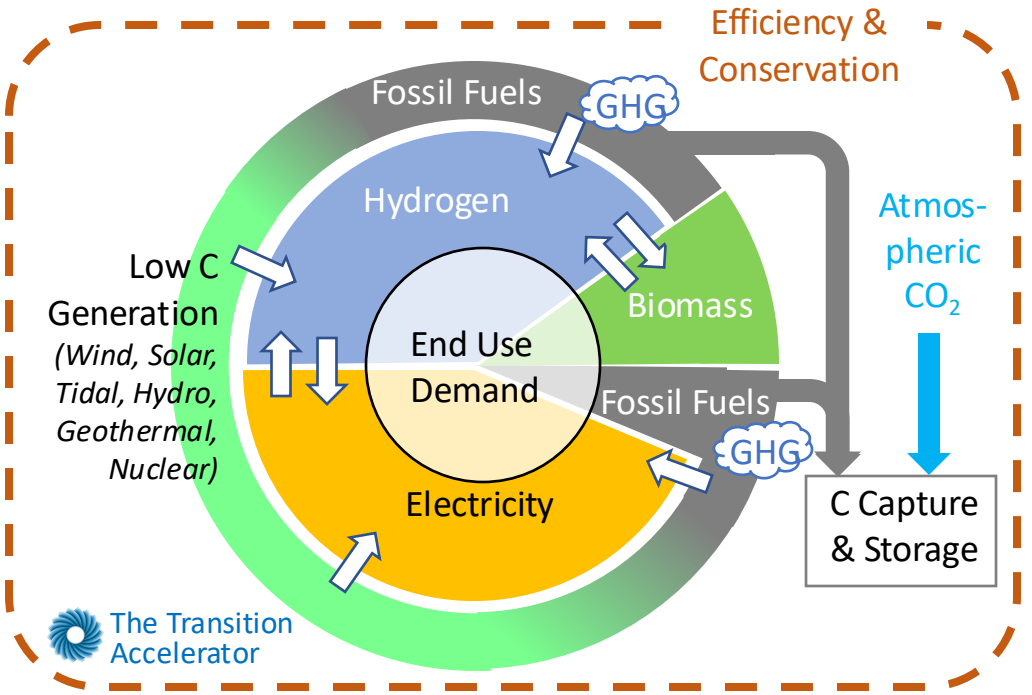
- *How can Canada 'win'?*
- *What are the best transition pathways?*

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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The Transition Accelerator / L'Accélérateur de transition

- *How can Canada 'win'?*
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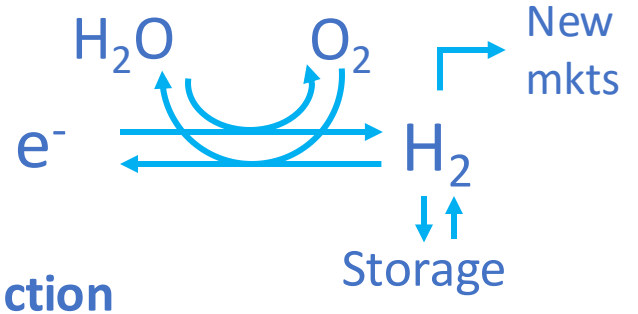
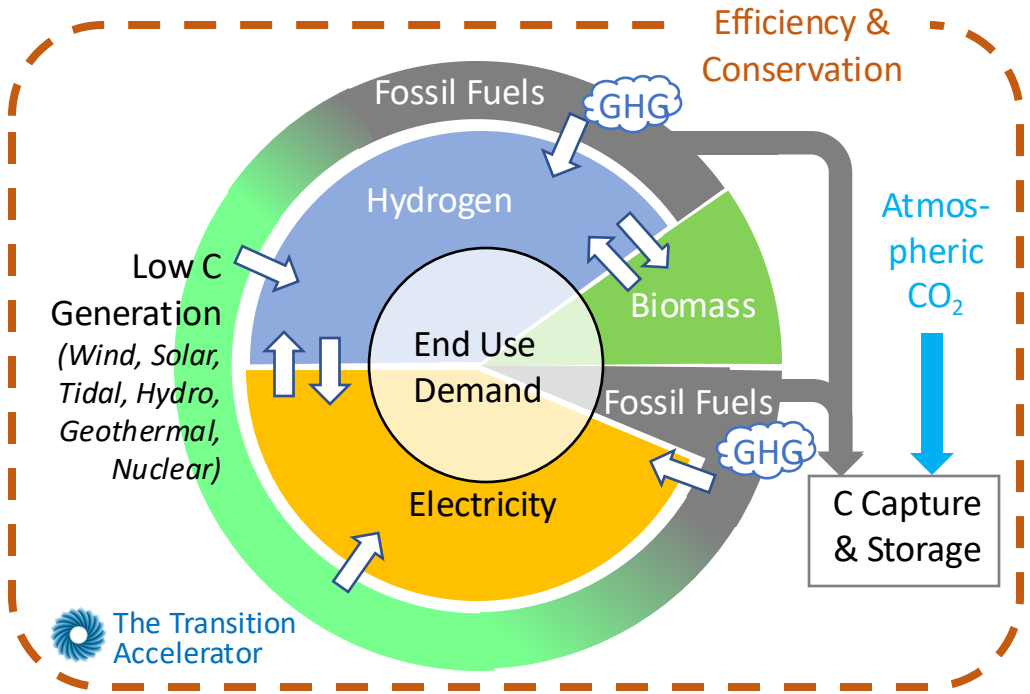
Why Hydrogen (H_2)?

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**



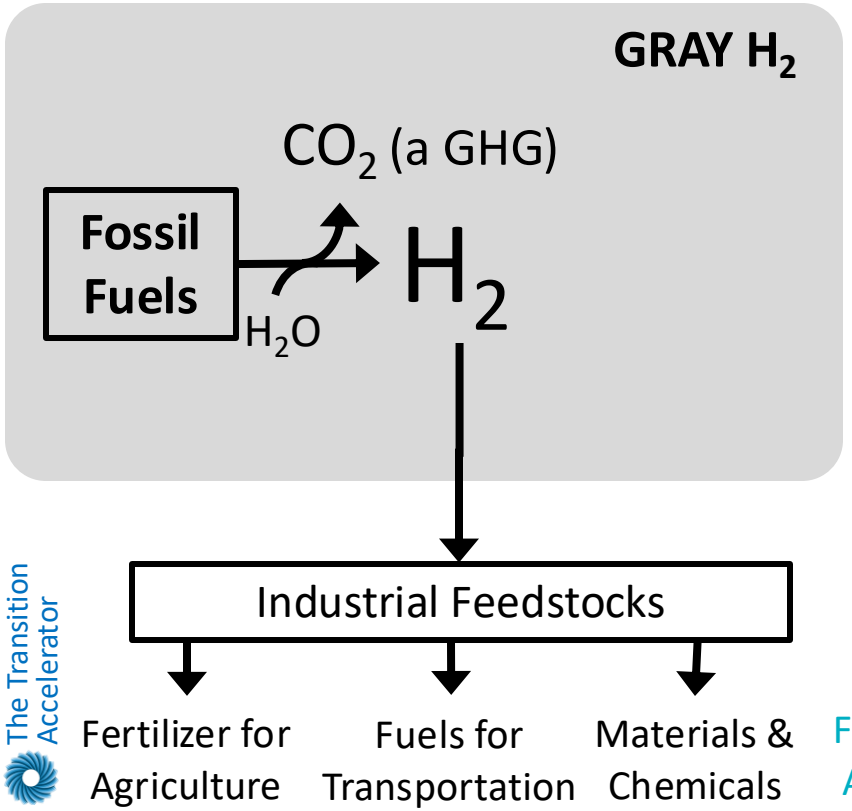
3. **Supports biofuel production**

Net-Zero Energy System

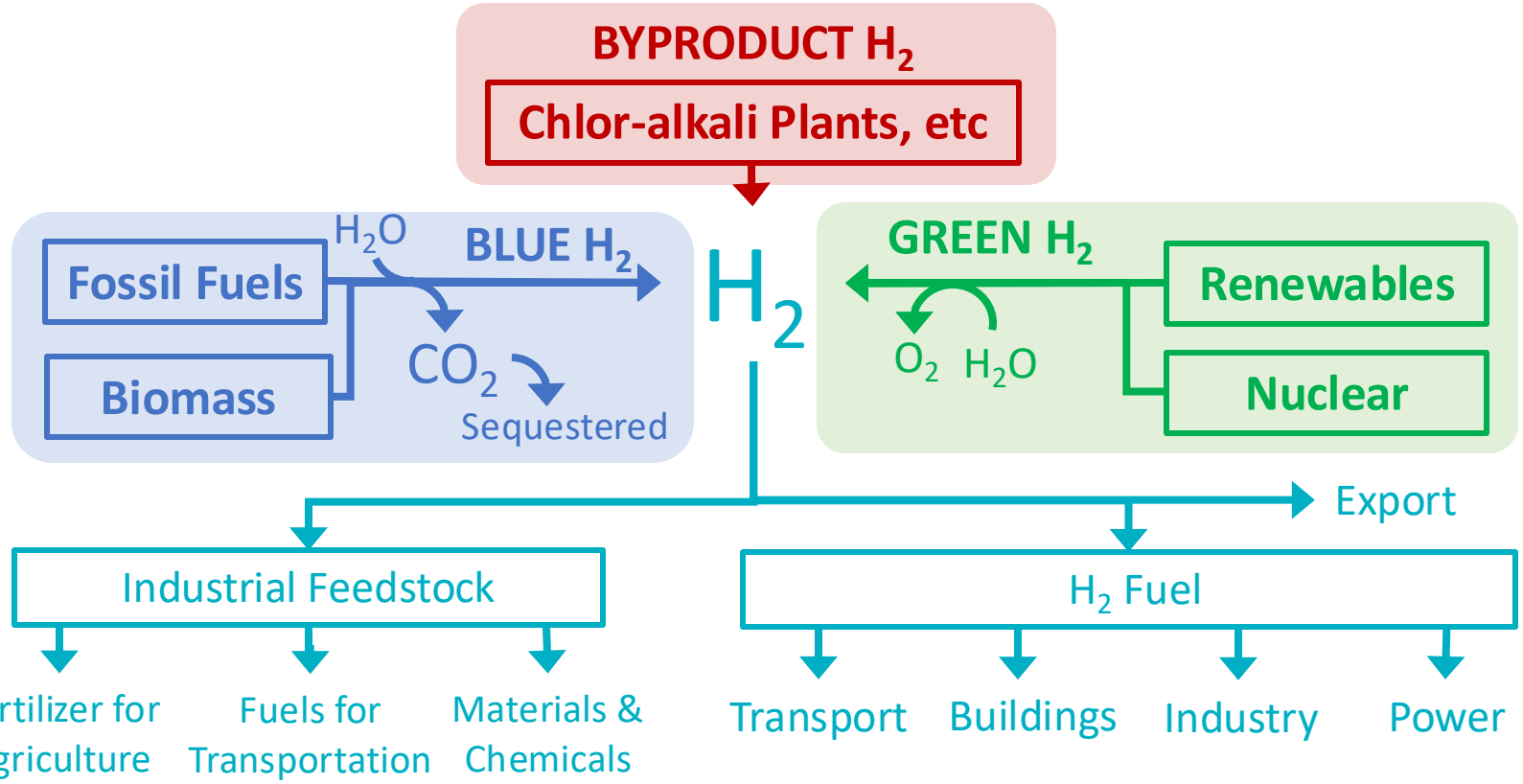


Towards a New Hydrogen (H_2) Economy

H_2 Today (Can: ~8.2 kt H_2/d)



H_2 in a New, Net-Zero Energy System



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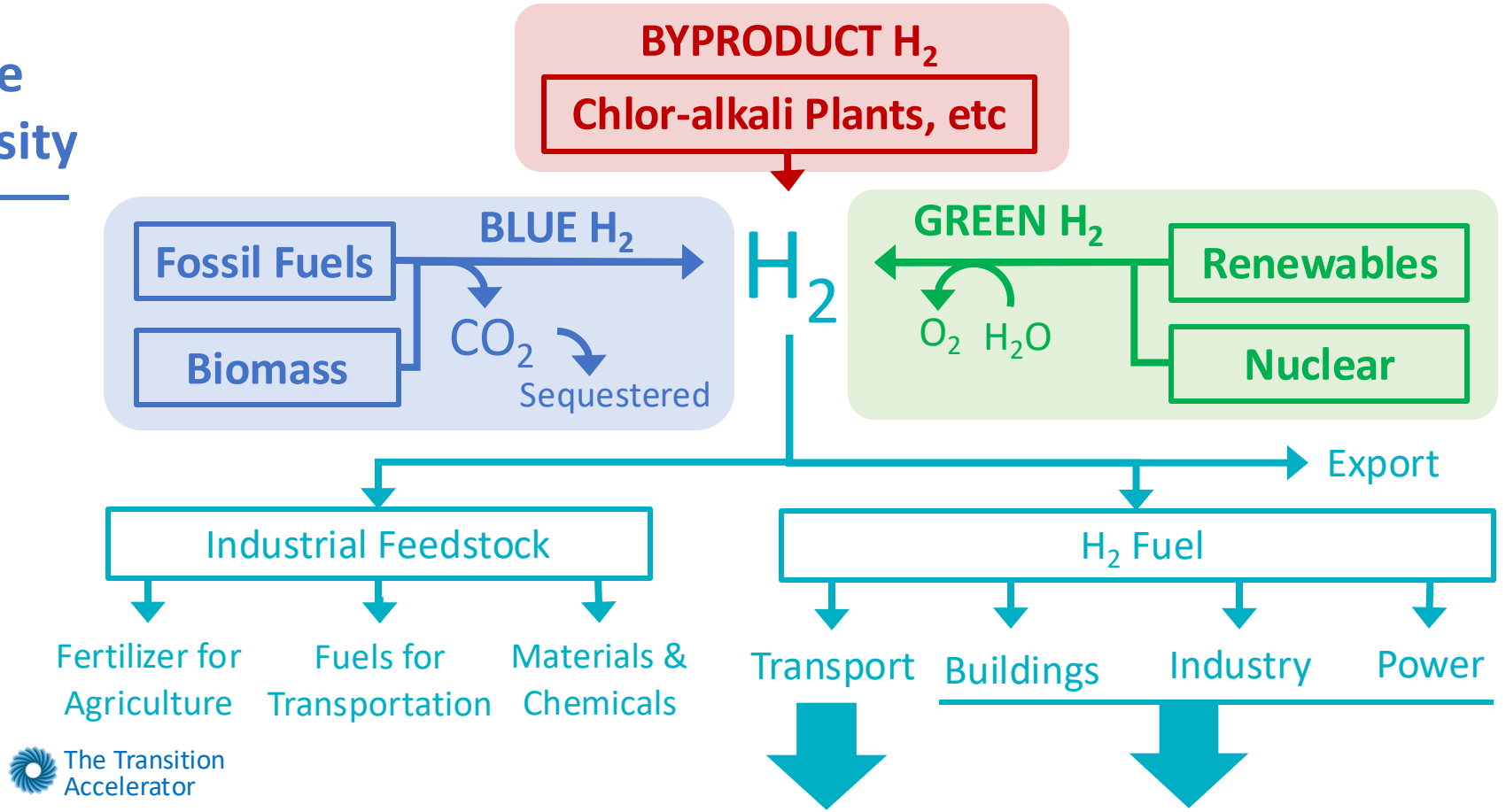
Canadian Market Potential:
Domestic: ~$50B/yr
Export: ~$50B/yr

From
Layzell et al. 2020

What About the Environmental Footprint?

Life Cycle GHG Intensity

~3 $\frac{kg\ CO_2e}{kg\ H_2}$



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Life Cycle GHG Intensity

~0.8 to 3 $\frac{kg\ CO_2e}{kg\ H_2}$

Reduction in Life cycle C Emissions

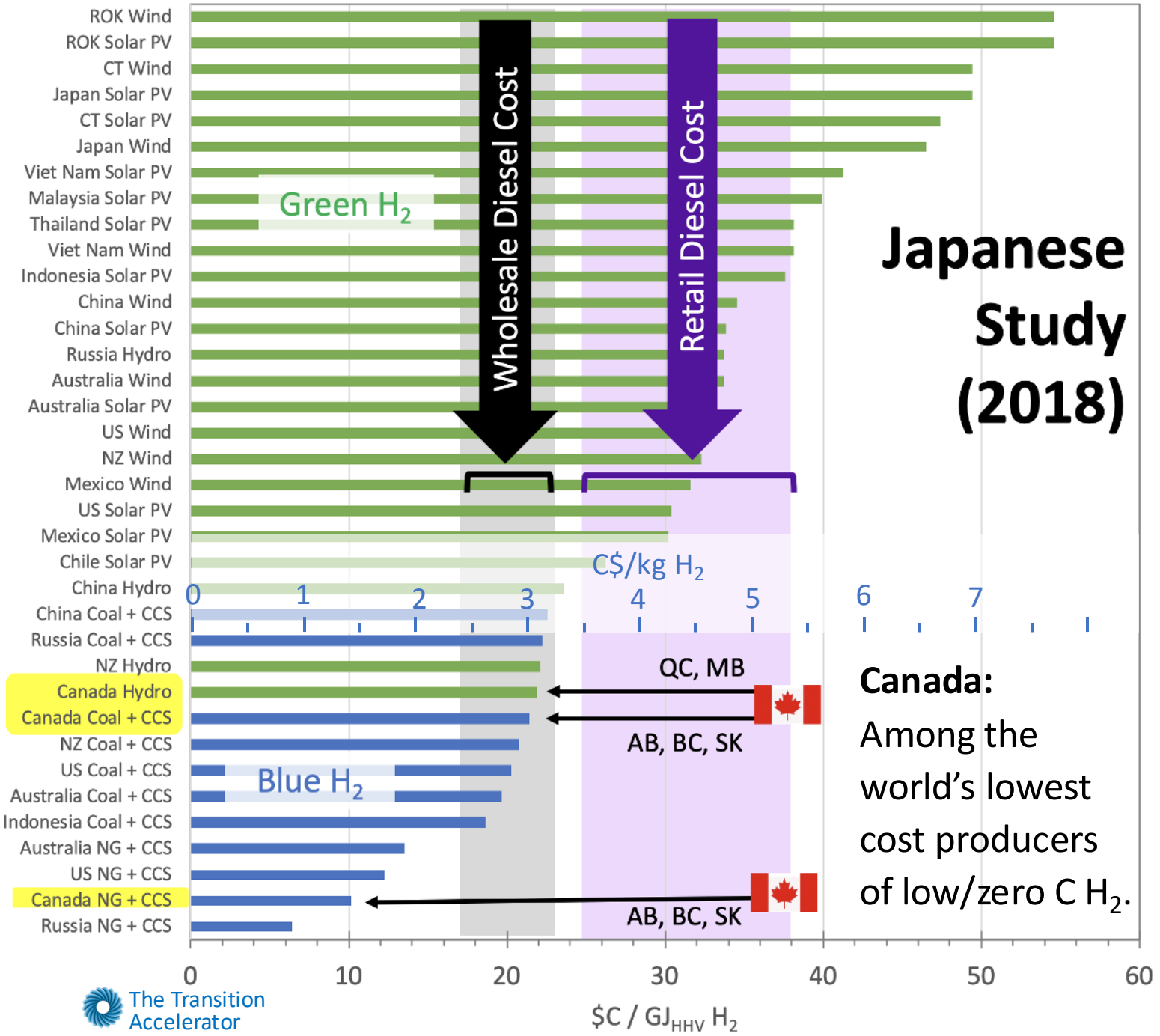
80% to 95%

67% to 90%

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

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

Alberta can make blue hydrogen at 1/2 the wholesale (1/3rd the retail) cost of diesel



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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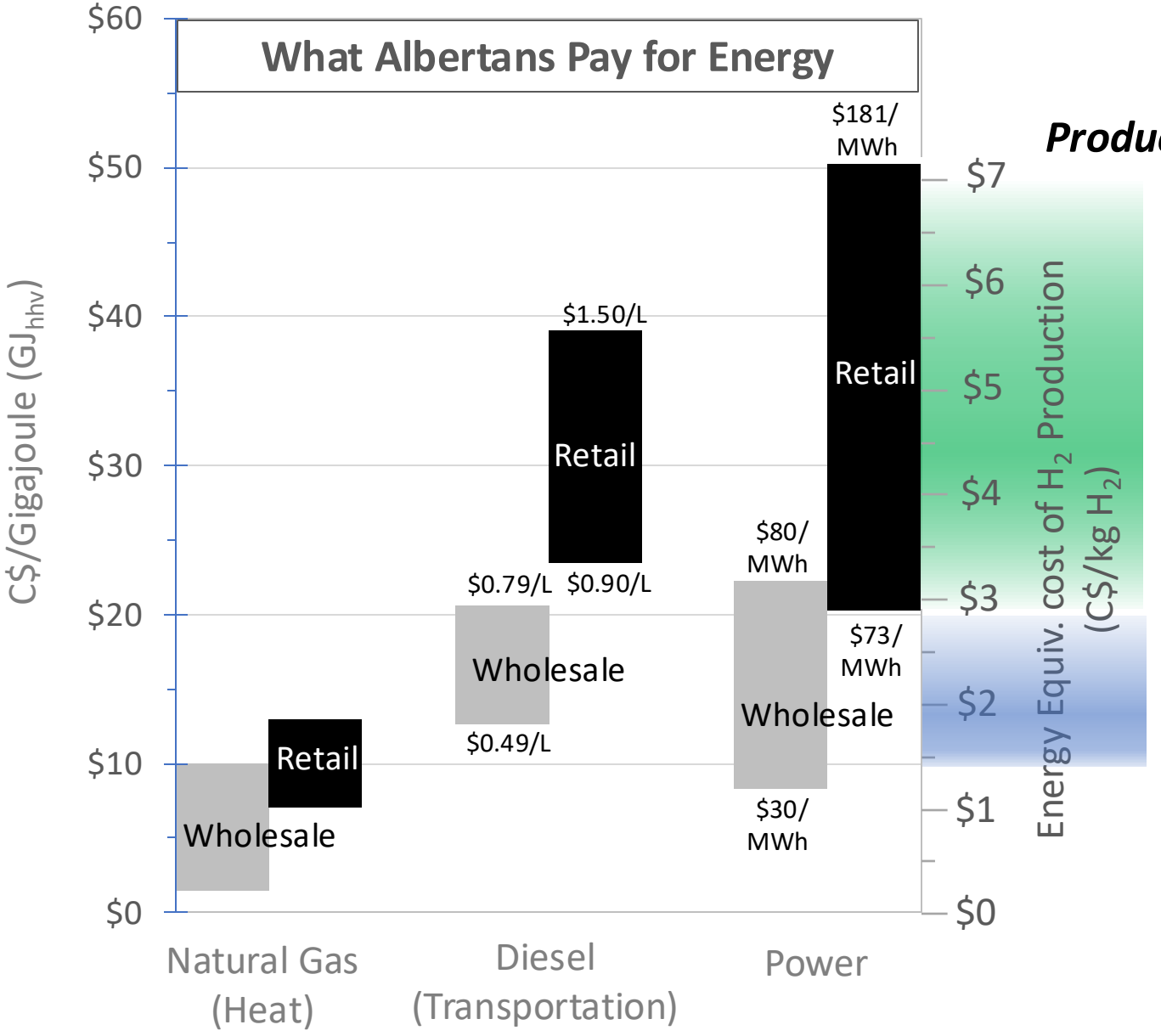
What Markets for Hydrogen are Most Promising?…



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

Blue H_2
(Lower costs @ larger scales)

Heavy Transportation:

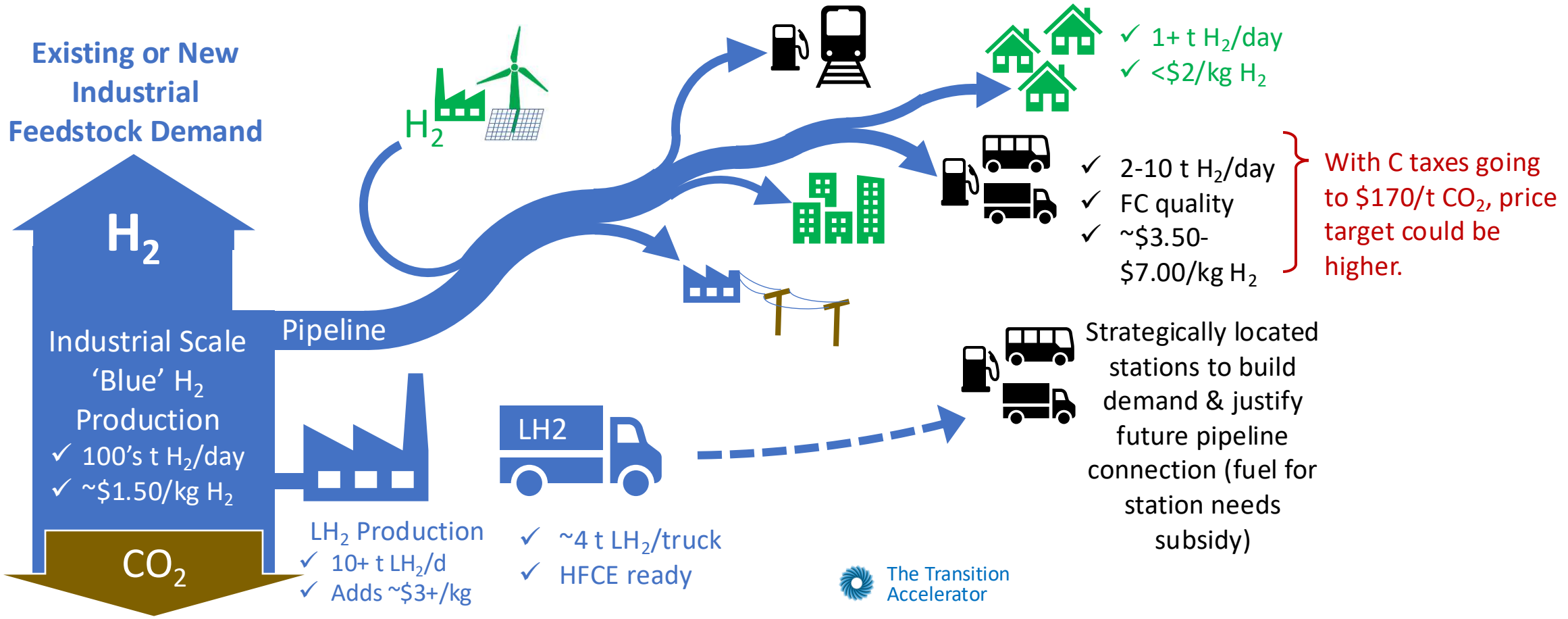
Offers the market where H_2 is most likely to be **economically viable** in the short to medium term.

More Challenging:

- ❑ Space/ water heating
- ❑ Industrial Heating
- ❑ Power generation

… but H_2 is likely to be the best net-zero choice for these sectors.

Strategy for Deploying a Fuel-Hydrogen Energy System



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

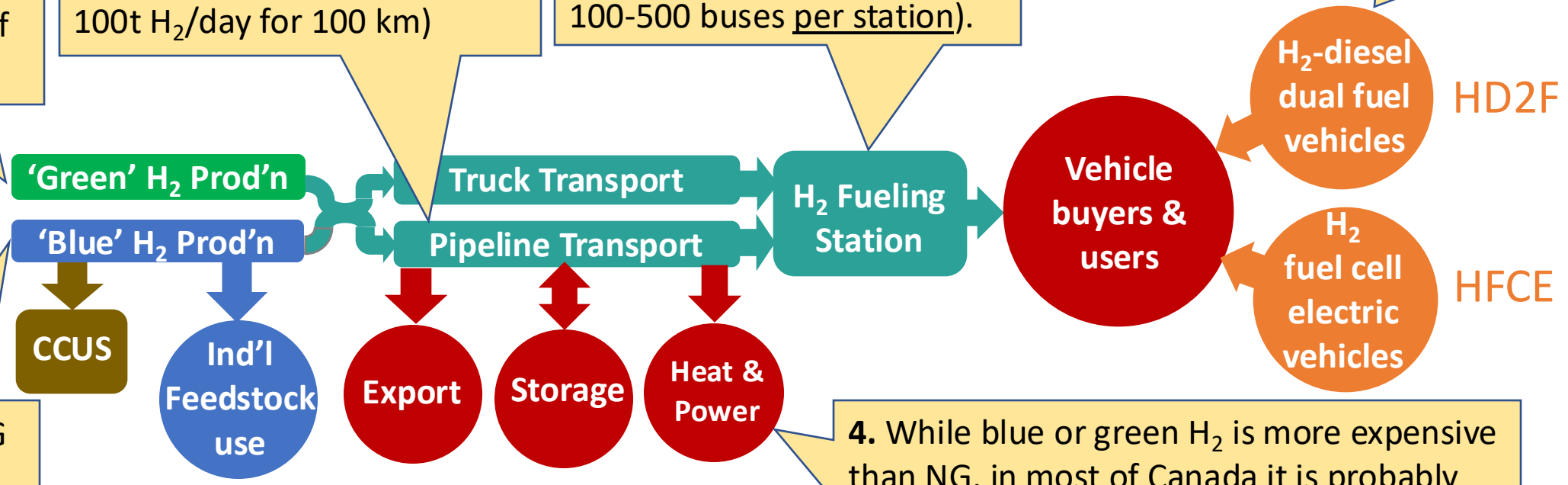
The Challenge of Scale in a Fuel Hydrogen Energy System

6. Green H_2 production from renewables will benefit greatly from a pipeline network built on the back of blue H_2.

3. Truck transport of H_2 to HFS is very expensive. H_2 pipeline is ideal, but to keep cost <$1/kg H_2, need flow of about 1X tH_2/d for each X km. (e.g. 100t H_2/day for 100 km)

1. To be economically viable, and deliver H_2 at an acceptable price, HFS must be at least 2-10t H_2/d (so need 40-200 HD trucks or 100-500 buses per station).

2. While HFCE trucks are the ultimate 'vehicles of choice', HD2F vehicles can help 'get to scale' quickly with minimal risk to carriers.



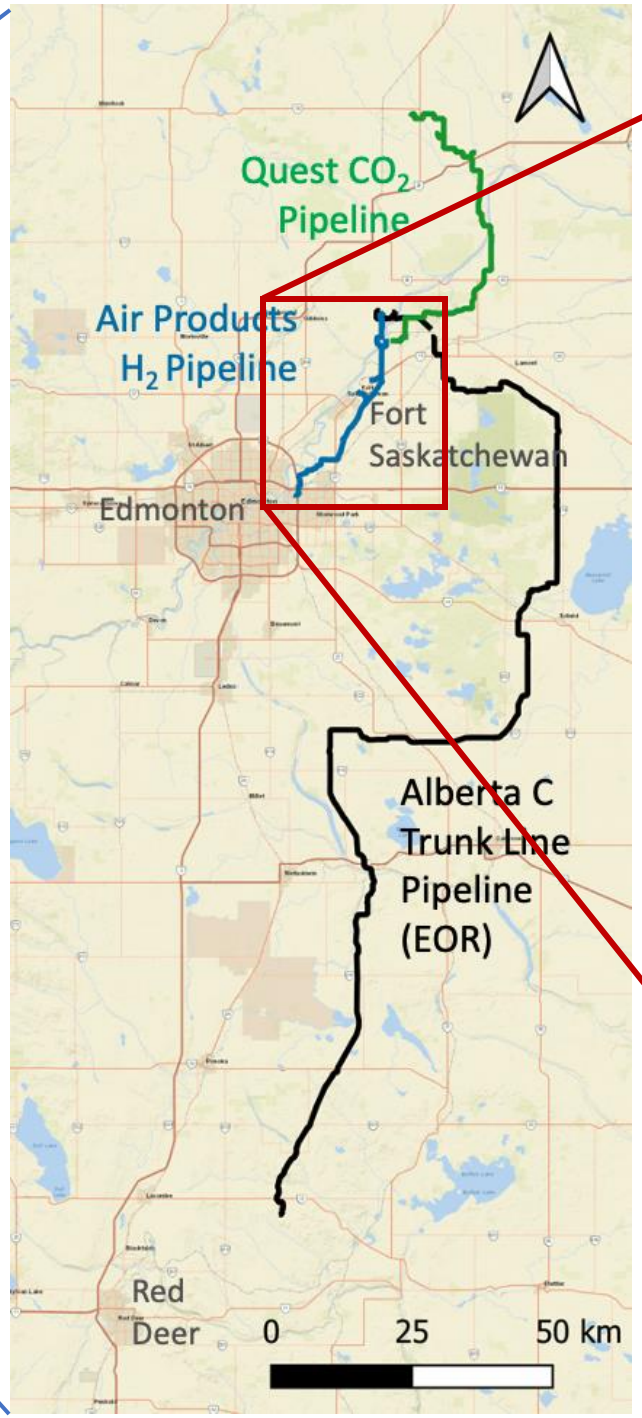
5. Blue H_2 (from NG or oil with CCS) will need to meet rigorous standards [<1 kg CO_2/kg H_2 + 8 kg CO_2/kg H_2 to CCUS]

4. While blue or green H_2 is more expensive than NG, in most of Canada it is probably the best solution for space heating in a net-zero energy system. This demand could help support infrastructure investments.

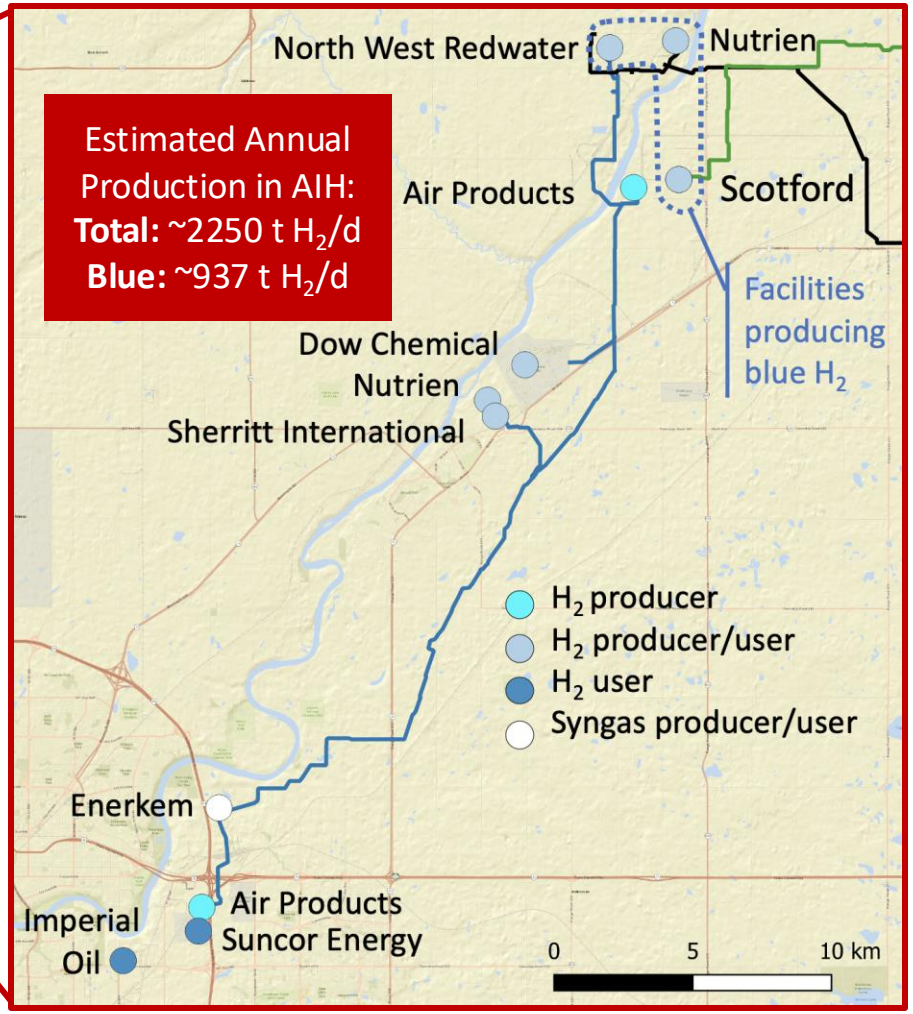
Hydrogen in Alberta

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

Projects being Deployed

AZETEC

ALBERTA ZERO-EMISSION TRUCK ELECTRIFICATION COLLABORATION

AMTA Alberta Motor Transport Association

EMISSIONS REDUCTION ALBERTA

Natural Resources Canada / Ressources naturelles Canada

Canada

The Transition Accelerator

BALLARD DANA HTEC

FREIGHTLINER

SUNCOR ENERGY

CESAR CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH

ZEN and the art of CLEAN ENERGY SOLUTIONS

- Design + build HFCE HD (63.5 t_{gross}) trucks
- Edmonton → Calgary return;
- Refueling station in Edm and Calgary
- Road trials starting in Q4, 2022

ATCO

EMISSIONS REDUCTION ALBERTA

FORT SASKATCHEWAN HYDROGEN BLENDING PROJECT

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

CP

HYDROGEN-POWERED LINE-HAUL FREIGHT LOCOMOTIVE

METHANE PYROLYSIS PROJECT

EMISSIONS REDUCTION ALBERTA

$CH_4 \rightarrow 2H_2 + C$

EKONA

APPLIED FOR:

HYDROGEN FUEL CELL TRANSIT BUS DEMONSTRATION PROJECT

Projects in Development

H_2-DIESEL DUAL FUEL TECHNOLOGY

- ❑ Integrating H_2 into ECU for Cummins engines
- ❑ Retrofit of diesel vehicles to take ~30+% of energy from H_2;
- ❑ Important 'bridge' technology;
- ❑ Valuable in creating fueling station demand for H_2.
- ❑ Potential to partner with fuel suppliers & carriers

ULEMCo
ultra low emission mileage company limited

hydra

UNIVERSITY OF ALBERTA
QUAECUMQUE VERA

Koch lab.

Cummins

NORTH AMERICAN CONSTRUCTION GROUP

HYDROGEN FUEL CELL VEHICLE TRIALS

Example Vehicles

Toyota Murai
(Avail: now)

New Flyer Bus
(Avail: now)

Hyzon Truck
(Avail: Q4, 2021)

Nikola Truck
(Avail: Q4, 2022)

Hyundai Truck
(Avail: ??)

AMTA Alberta Motor Transport Association

H_2 Truck Roadshow

To provide users with 'hands-on' experience:

- ❑ *Engage Municipalities, AMTA members;*

Features:

- ❑ Vehicles will be leased
- ❑ Access to fuel in Edmonton & Calgary
- ❑ If successful, companies will buy & support fueling infrastructure.

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Conclusions

- Many nations of the world, including Canada, are committed to transitioning to net-zero emission energy systems;
- Alberta is poised to lead & benefit from 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, supported by pipelines
- We need to start now!

Thank you!

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