Transforming Energy Systems:
Towards a Hydrogen Economy Anchored by Freight Transport

David B. Layzell, PhD, FRSC.

Co-founder & Research Director, The Transition Accelerator

Professor & Director, Canadian Energy Systems Analysis Research (CESAR) Initiative, University of Calgary, Calgary, AB

E: dlayzell@ucalgary.ca; W: www.cesarnet.ca or www.transitionaccelerator.ca

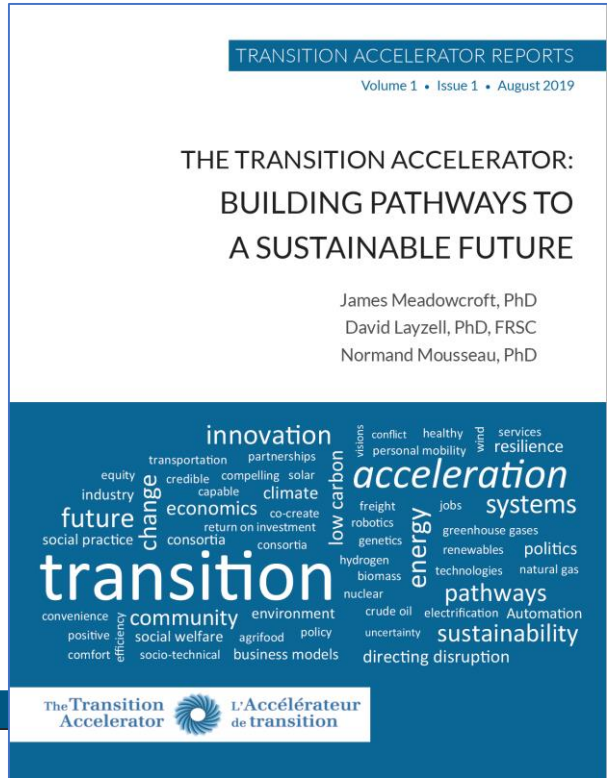
UNIVERSITY OF CALGARY

CESAR CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH

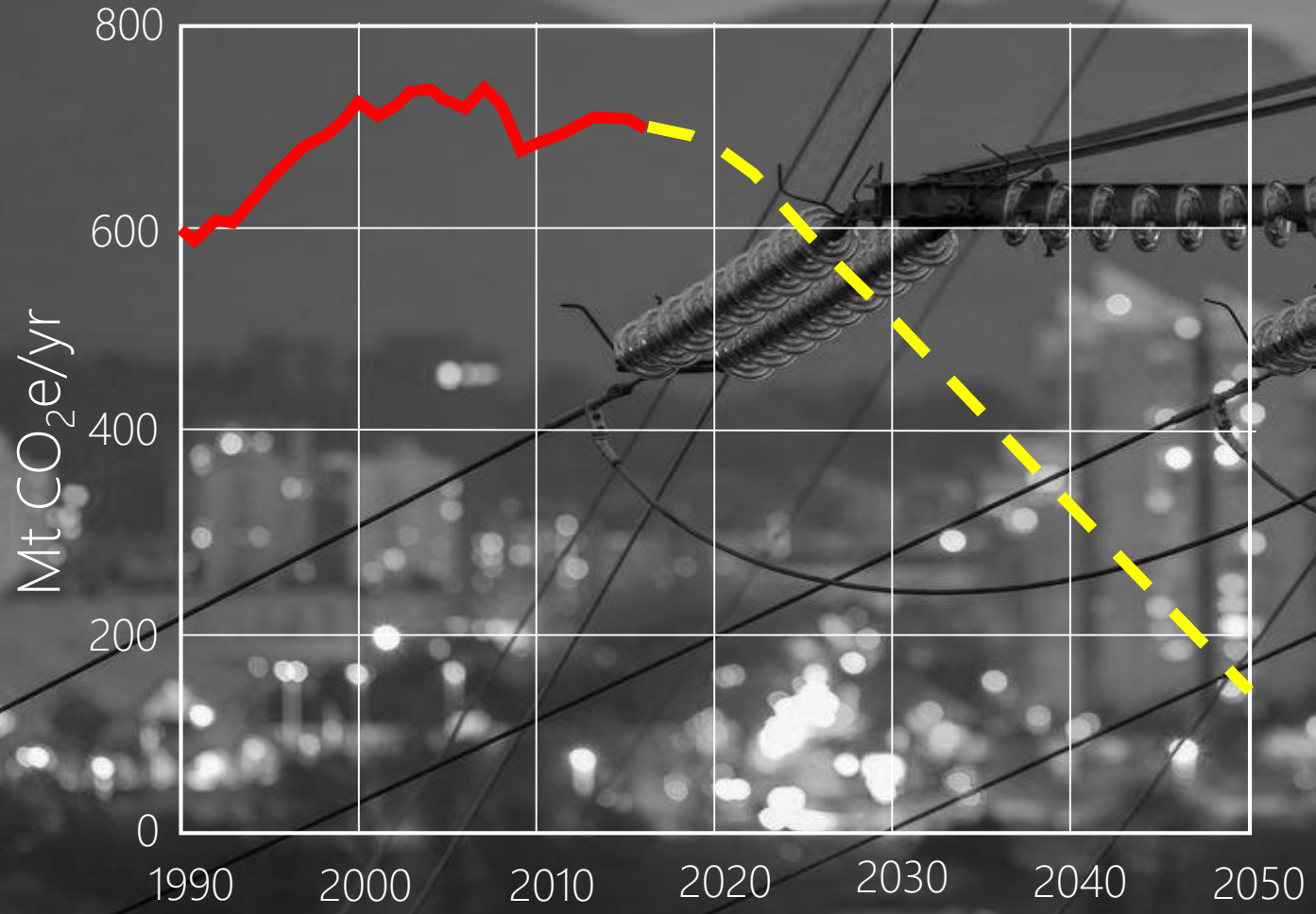
The Transition Accelerator L'Accélérateur de transition

OUTLINE

1. *The Transition Accelerator: philosophy & methodology*
2. *Alberta's energy systems: an overview*
3. *A case for a hydrogen economy anchored by freight*
4. *Discussion*



Canada's GHG Challenge



Transformative Changes are Needed:

...in our fundamental socio-technical systems:

- *Personal mobility*
- *Goods movement*
- *How we live*
- *What we eat*
- *Industrial processes*

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PROBLEM:

Many – perhaps most – Canadians do not see climate change as a ***sufficiently compelling*** reason to make major changes in their way of life…

…especially if there is a perceived cost.

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Maybe the climate change problem isn't BIG ENOUGH…

…we have precedents:

- International trade agreements;
- Collective bargaining;
- …

*…maybe we need to expand the problem space to include issues that **are compelling** to Canadians because solutions offer:*

- ***More convenience;***
- ***Lower costs;***
- ***Greater comfort;***
- ***Improved health;***
- ***Higher quality of life***

Example: Personal Mobility

- ~13% of Cdn GHGs

Other, more compelling reasons for transformative systems change:

- Accidents
- Congestion
- Air pollution
- High cost of vehicle ownership
- Parking
- Urban Sprawl

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Disruptive Innovations in Personal Mobility

- Autonomous, connected vehicles
- Car sharing
- Electric vehicles
- Societal changes

New business model:
"Mobility-as-a-Service (MaaS)"

If optimally implemented, MaaS could accelerate personal vehicle electrification and achieve other highly compelling benefits…

… but there is a need for
'Directed Disruption'

Image from Waldrop 2015. Nature 518: 20-24

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‘Directing Disruption’ in Personal Mobility

Encourage

- ❑ AVs electrification (BE or HFCE)
- ❑ Shared AVs (MaaS)
- ❑ MaaS supporting/extending public transit
- ❑ Pick up/drop off zones (PUDO)
- ❑ People focused communities

Discourage

- ❑ Int. combustion engine AVs
- ❑ Privately-owned AVs
- ❑ MaaS replacing public transit
- ❑ Parking
- ❑ Car focused communities

We need to build positive, shared visions for transition pathways that addresses business and societal challenges, including climate change.

The Grand Challenge:

To connect people's desire for:

- More convenience
- Lower costs
- Greater comfort
- Improved health
- Higher quality of life

...with the opportunity to steer transformative change in a low-carbon direction.

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Building Transition Pathways

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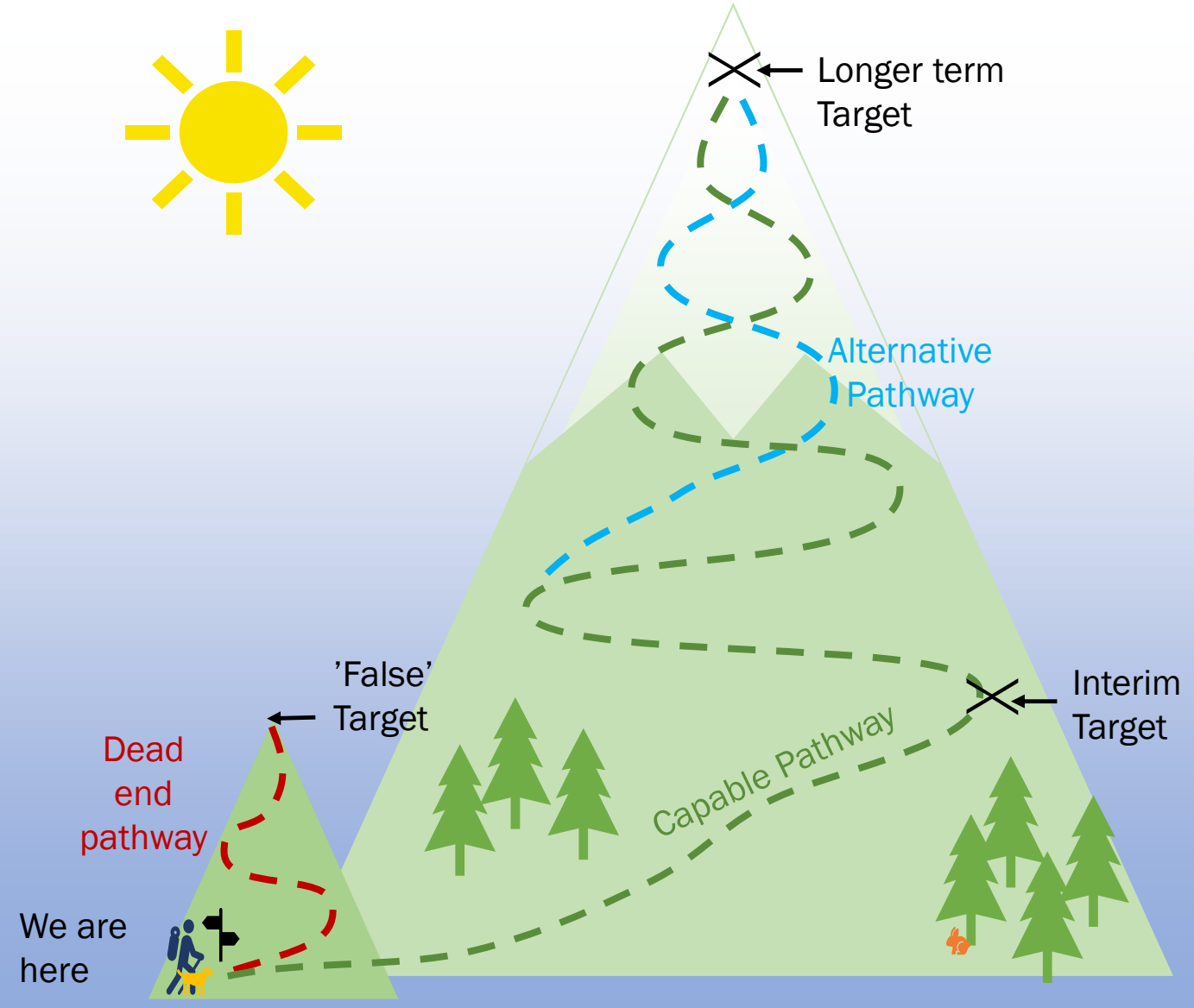
Requirements of a Transition Pathway

1. **CREDIBLE** (Technically, economically, socially)
2. **COMPELLING** (Desired by key stakeholders)
3. **CAPABLE** of achieving the target(s).



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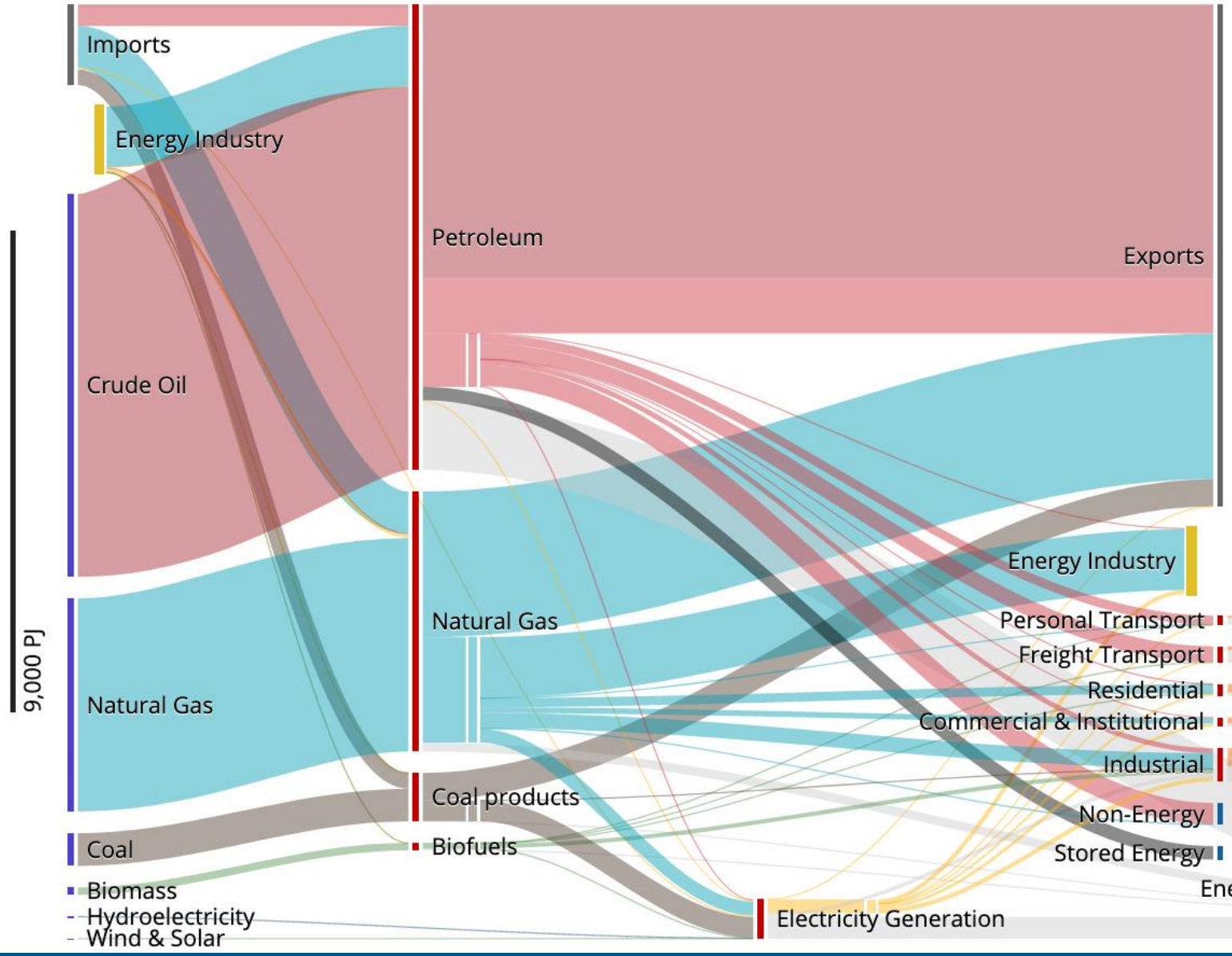
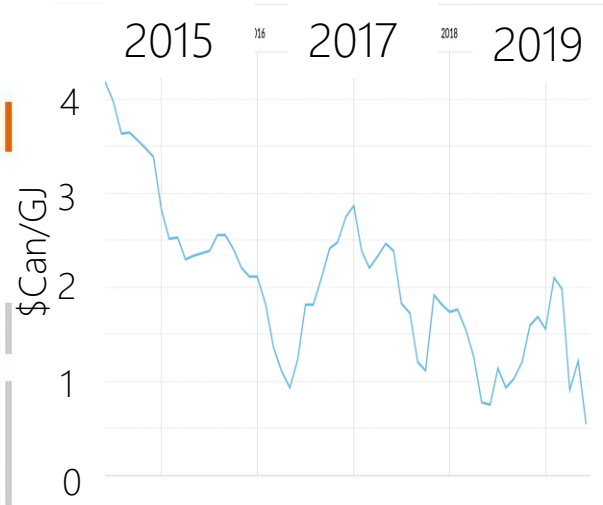
Alberta's Total Energy System (2013) PJ/yr



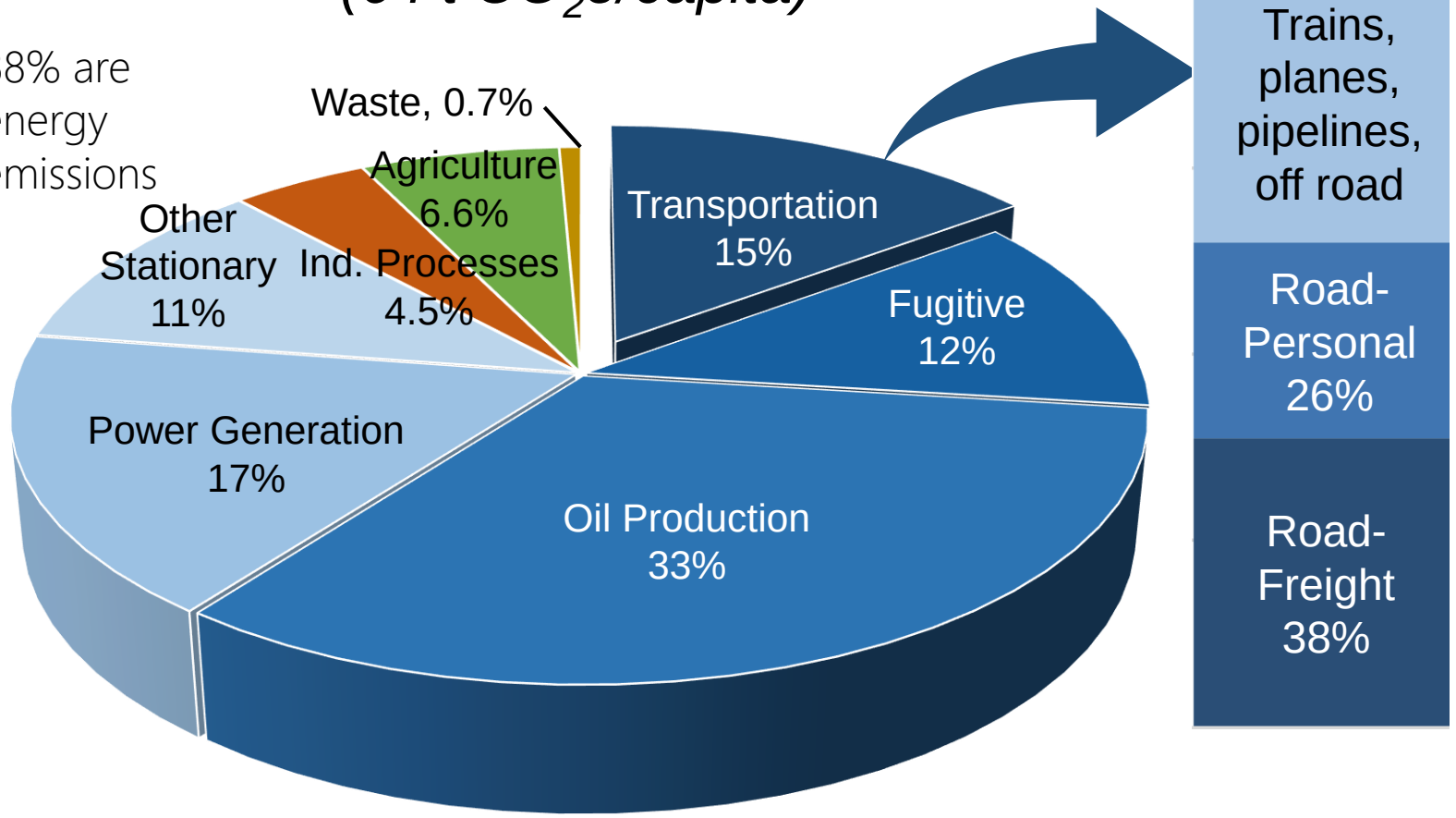
- Major (fossil) energy producer, user & exporter
- Discount prices:
  - ✓ Oil: $10-$40 below WTI (typically -$14/bbl)
  - ✓ NG: $0.55/GJ



Alberta's Greenhouse Gas Emissions

273 Mt CO_2e/yr in 2017
(64 t CO_2e/capita)

88% are energy emissions



Mostly gasoline

Mostly diesel

Transformative Reductions Needed:

- -30% by 2030
- -80% by 2050

Also, oil production and a proportion of fugitive and power generation emissions are linked to transportation fuel demand (>50%)

CANADA'S RESPONSE TO CLIMATE CHANGE

Current Strategy:	Problems:	Proposed Strategy
Oil & Gas Reduce C intensity associated with making the fuels (diesel, gasoline, etc) that the world is working hard to <u>stop using</u>.	➢ *60%-80% of the life cycle emissions are associated with <u>fuel combustion</u> (not production).*	❑ Build new energy systems requiring zero emission fuels (e.g. hydrogen, electricity) that Canada can produce with little or no GHG emissions.
Other Sectors Sectors now served by fossil fuels (transport, industry and space/ water heating) shifting to <u>Electrification</u>	➢ *New, dispatchable C-free power (hydro, nuclear) is expensive and often not supported by public;* ➢ *Renewables like wind and solar are intermittent, so grid integration is challenging;* ➢ *For some applications (e.g. heavy transport), grid electrification does not work well*	❑ Hydrogen production from electrolysis could add value to excess and/or intermittent renewable power.

Both Battery & H_2 Fuel Cell EVs Make Sense

Grid to Battery Electric Vehicles:

Grid:
- ❑ Low carbon

Personal Mobility
- ❑ Short urban trips

Freight Transport
- ❑ Last mile deliveries
- ❑ Drayage

Why Alberta should take a close look at a hydrogen economy…

Hydrogen Fuel Cell Electric Vehicles:

Grid:
- ❑ High carbon
- ❑ Surplus/low cost/low C power

Personal Mobility
- ❑ Longer intercity trips
- ❑ Heavy duty, or extensive vehicle use

Freight Transport
- ❑ Heavy-duty, long distant haulage
- ❑ Ships, trains, planes

Other
- ❑ Fossil C resources
- ❑ Holey rocks to store C

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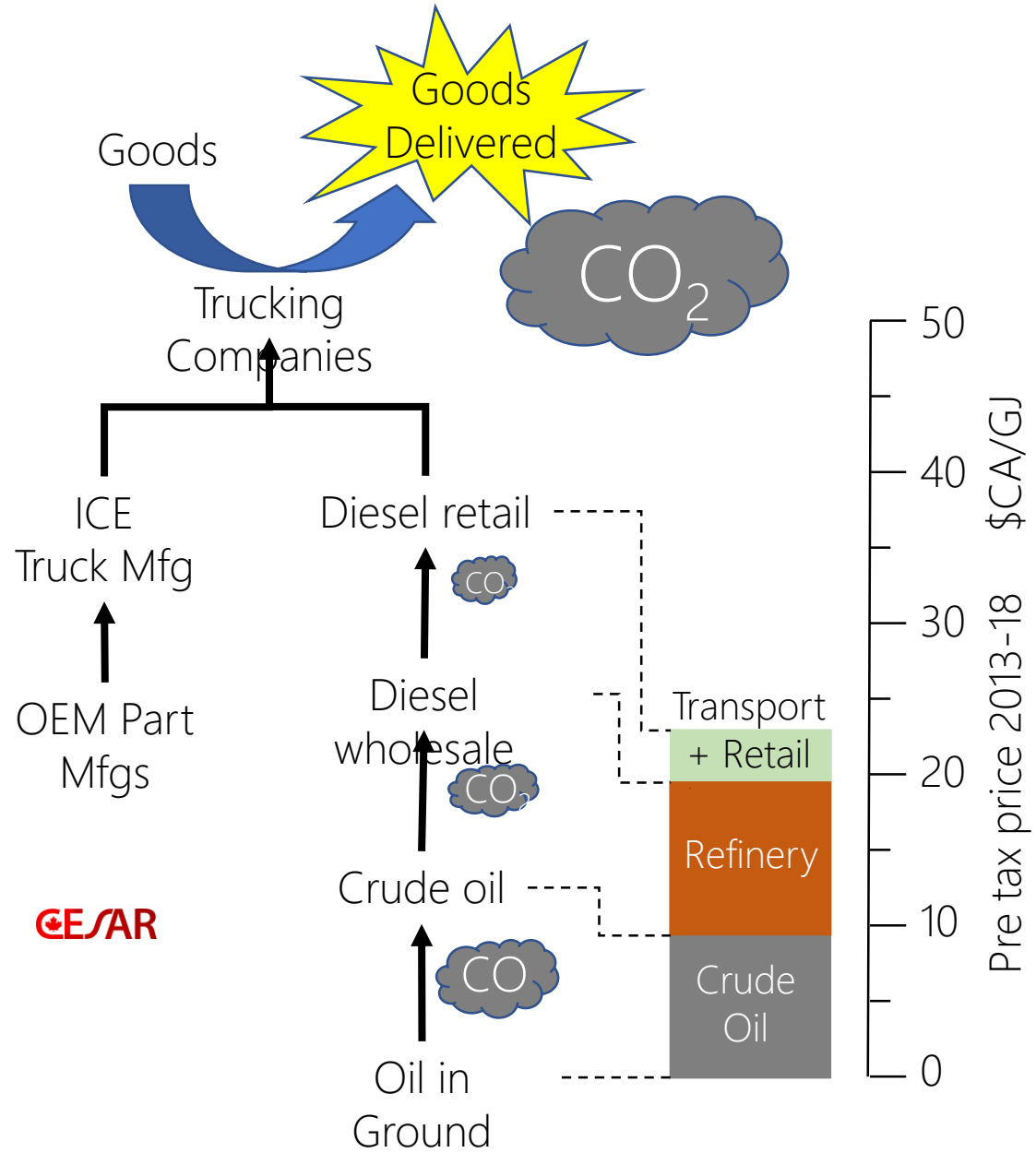
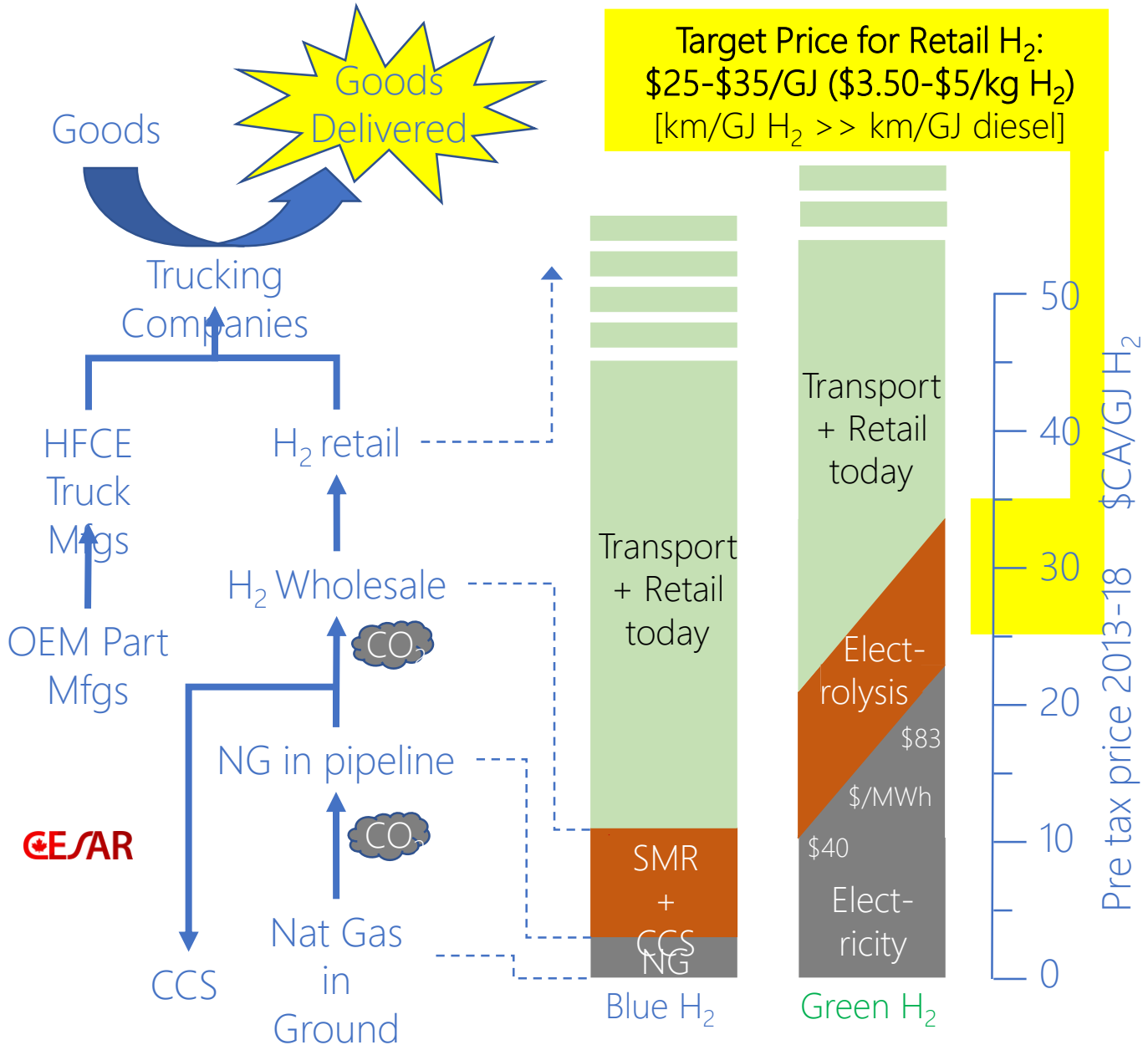
WHY NOW FOR THE H_2 ECONOMY?

- Advances in:
  - Hydrogen fuel cells (lower costs & size, improved performance)
  - Battery technologies (hybrid vehicles; H_2=range extender and power boost)
  - Electric motor technologies (better to serve the vehicle market)
- New market focus: NOT personally owned, LD vehicles, but heavy vehicles & exports (One HFCE vehicle uses a lot of fuel)
- A broader realization that climate change is happening and **transformational**, *not incremental*, change is needed.
- We need to start now and NOT wait for more technology advances (and we can)

A. Diesel-ICE Energy System

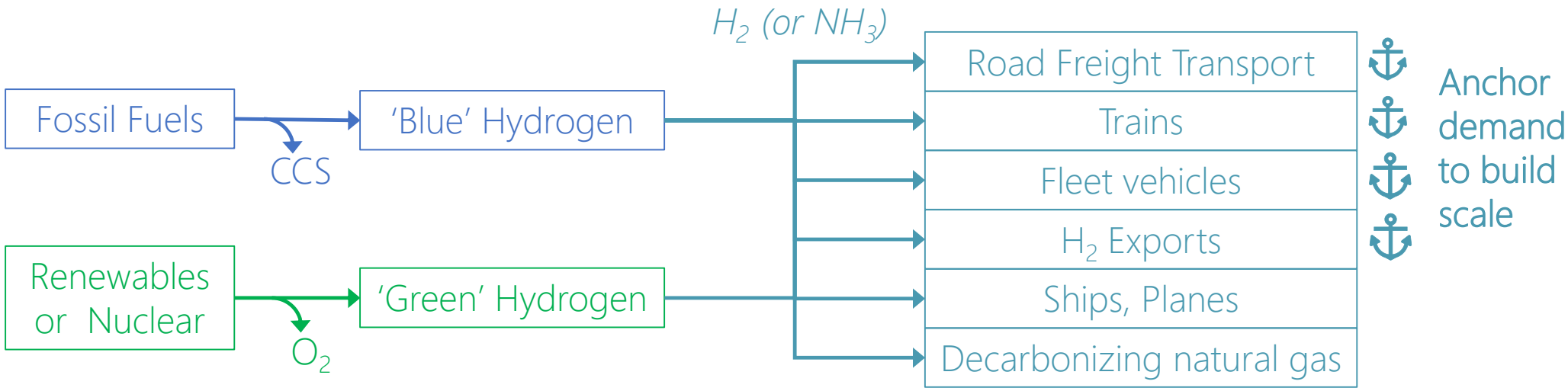


B. 'Blue' H_2-FCE Energy System



A Hydrogen Economy Anchored by Heavy Freight:
An Energy System that Works for all Parts of Canada

Proposed *New Energy System*



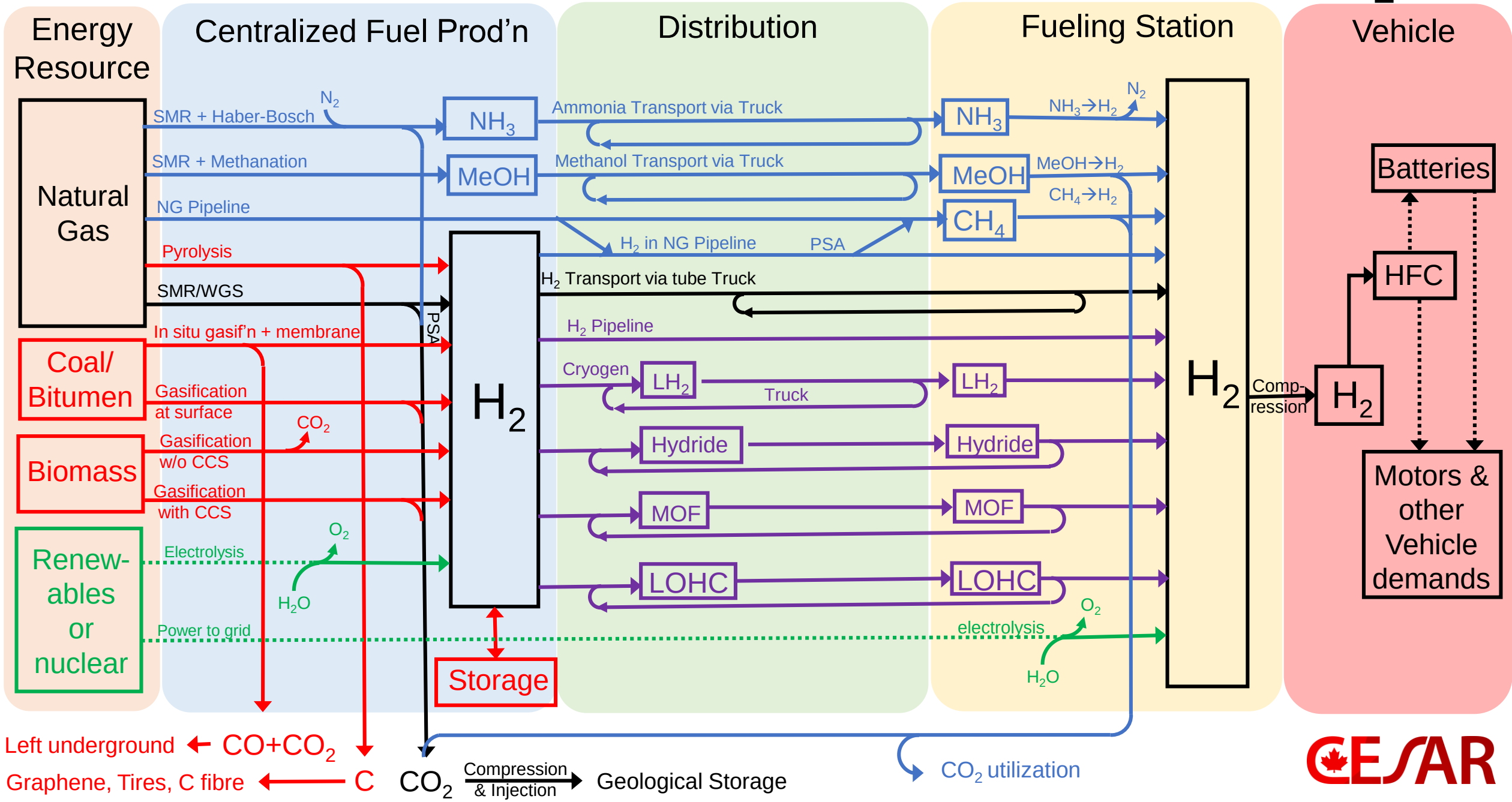
Why the Hydrogen Economy will Begin in Alberta

1. Per unit energy or km travelled, cost of H_2 production << cost of diesel;
2. Alberta can make 'blue' H_2 from fossil fuels, manage the carbon and show a profit for ½ to ¼ the cost of 'green' H_2;
3. Alberta has a large heavy freight sector and they want an alternative to diesel;

How to Realize the Potential:

- ❑ Work with sectors like heavy freight to build demand for hydrogen fuel cell electric vehicles in strategic locations;
- ❑ Work with innovative companies to provide 2-10 t H_2/day at strategically-located fueling stations at competitive prices (<$5/kg H_2 or $35/GJ H_2);
- ❑ Create a new, low C energy system in Alberta then grow into other jurisdictions along road, rail and pipeline corridors;
- ❑ With infrastructure in place, 'green' hydrogen can compete

Energy Systems for the Production & Distribution of H_2?



AZETEC

ALBERTA ZERO-EMISSION TRUCK ELECTRIFICATION COLLABORATION

An Industry-Led, $15M Consortia Supported by Emissions Reduction Alberta with $7.3M.

Funding Support:

EMISSIONS REDUCTION ALBERTA

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Lead Applicant:

AMTA Alberta Motor Transport Association

Carriers:

Trimac

Bison Transport

Vehicle Design, Components and Manufacturing:

FREIGHTLINER

nordresa

BALLARD

DANA

Fueling System:

HTEC Hydrogen Technology & Energy Corporation

Research, GHG Accounting and Commercialization:

University of Calgary

CESAR Canadian Energy Systems Analysis Research

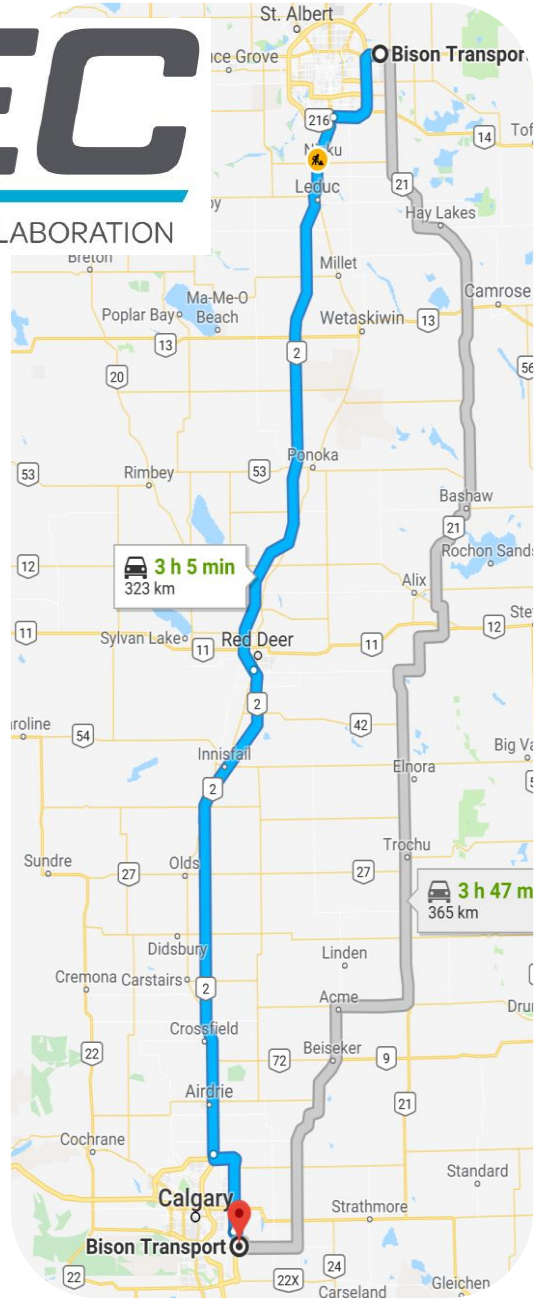
energyfutureslab powered by The Natural Step Canada

Project Management:

ZEN and the art of Clean Energy Solutions

AZETEC

ALBERTA ZERO-EMISSION TRUCK ELECTRIFICATION COLLABORATION



FEATURES:

Two H_2 Fuel Cell Electric Class 8 Trucks

- ✓ 700km Range
- ✓ Heavy Weight (63.5t)
- ✓ Zero Tailpipe Emissions

Operated on AB Highways by AB Carriers

- ✓ Daily Trips Between Edmonton and Calgary

Hydrogen Produced from AB natural gas

- ✓ Steam Methane Reformed (no C mgmt.)
- ✓ Cascade Refueling

Timetable:

- ✓ July 2019 to June 2021: Build vehicles
- ✓ July 2021 to Dec 2022: Test Vehicles

Commercialization Strategy

- ✓ Build consortia interested in 100+ HFCE vehicles and large ‘blue’ H_2 fueling stations

Road Freight Transport:

the 'Anchor Tenant' in an Alberta Hydrogen Economy

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Strategy: to Engage…

Freight carriers

- ❑ 2 → 100 → 1000's trucks
- ❑ Focus on major routes & return to base
- ❑ Link to autonomous trucking

Vehicle and OEM mfg's

- ❑ Reduce cost by scaling prod'n
- ❑ Invest in Alberta

H_2 producers / delivery agents

- ❑ Provide fuel for a limited number of strategically placed, high volume fueling stations (2+ t H_2/day)
- ❑ Build on regional strengths for H_2 production / distribution

…through Pilots, Demonstration & Commercialization Initiatives

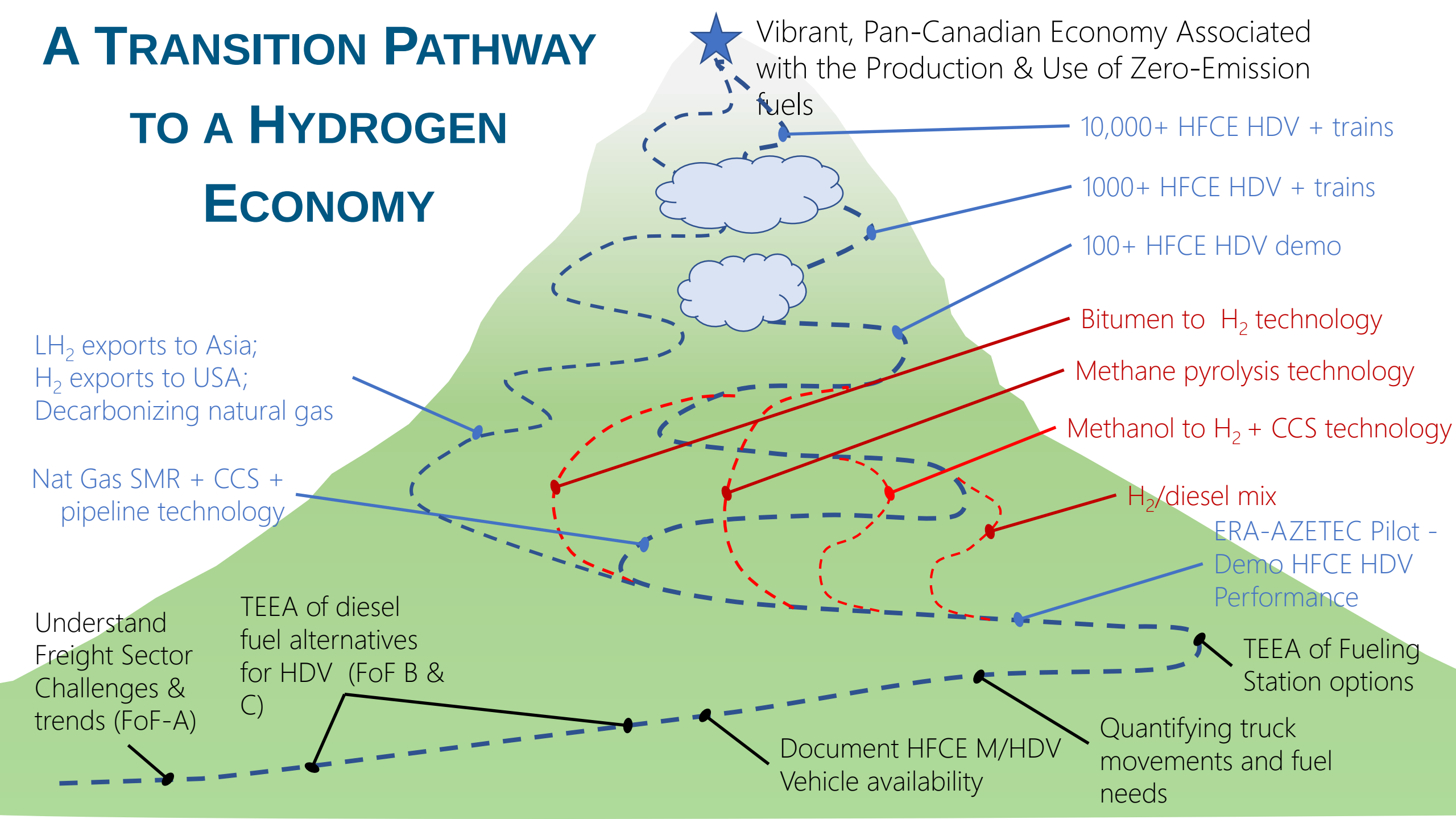
New Business Model for Long Distance Freight Movement

One company:

- Makes low or zero carbon H_2
- Provides H_2 at strategically-located fueling stations on major intercity routes with large goods movement.
- Buys and maintains HFCE tractors;
- Leases tractors (including fuel, maintenance etc) to trucking companies for a $/km rate
- Poised to implement with autonomous / platooning vehicles when technology is ready

Plus other investors have approach AZETEC about expanding to participate in this model

A Transition Pathway to a Hydrogen Economy



Building a Vibrant H_2 Economy