Technological, social and business model innovations / disruptions are transforming sectors and lives;

But whether disruptions solve our societal problems, or makes them worse, depends on decisions we make today;

The Accelerator approach is to ‘direct’ disruptions, to foster and drive transitions to novel system configurations that provide multiple superior societal outcomes ... including on the climate front;

**How?** Work with key actors to co-create positive **Visions** of the future, that lead to the definition of credible and compelling **Transition Pathways** to a better future. The Accelerator then builds industry-led consortia to start the journey.
FUTURE OF FREIGHT
CESAR SCENARIOS REPORTS

A: Trends & Disruptive Forces

B: Assessing Alternatives

C: Energy System Impacts
Future of Freight A
Understanding Trends & Disruptive Forces
The Road Freight Sector Today:

- High GHG emissions
- Air pollution
- Facing a labour shortage
- Low margins
- Sub-optimal load management (empty km)
- Congestion & accidents
- High cost of diesel engine maintenance

The industry wants change and is interested in innovative ideas.
Future of Freight B
Assessing Diesel Alternatives (TEEA)
FUTURE OF FREIGHT B
ASSESSING DIESEL ALTERNATIVES (TEEA)

Diesel Internal Combustion Systems

- Dominant (ubiquitous) technology
- Performance is predictable and accepted.
- Fuel supply chain is mature
- Future improvements are likely expensive and limited to incremental performance gains

27 Tonne Truck Travelling 750 km

Fossil Diesel – Internal Combustion Engine (FD-ICE)

26% Well to Wheel Efficiency
**Energy Cost Comparison**

- Comparing energy systems based on kinetic energy demand accounts for efficiency differences.
- Uncertainty in distribution costs for hydrogen is significant but suggests opportunity for cost reduction with scale and infrastructure development.
- Battery electric option has energy cost advantages.

### Mid-point estimates for kinetic energy cost

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (CAD $/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil @ $US47/bbl</td>
<td>0.00</td>
</tr>
<tr>
<td>Residue @ $5.94/GJ</td>
<td>0.00</td>
</tr>
<tr>
<td>Power @ $C42/MWh</td>
<td>0.00</td>
</tr>
<tr>
<td>NG@$C2.83/GJ</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Energy Systems:**
- FD-ICE
- BD-ICE
- G-BE
- NG-HFCE
- WS-HFCE

**Comparing Energy Systems:**

- **FD-ICE**
  - Refining:
    - Crude Oil @ $US47/bbl
  - Distribution & Retail:
    - Residue @ $5.94/GJ

- **BD-ICE**
  - Refining:
    - Power @ $C42/MWh
  - Distribution & Retail:
    - NG@$C2.83/GJ

- **G-BE**
  - Refining:
    - Crude Oil @ $US47/bbl
  - Distribution & Retail:
    - Residue @ $5.94/GJ

- **NG-HFCE**
  - Refining:
    - Power @ $C42/MWh
  - Distribution & Retail:
    - NG@$C2.83/GJ

- **WS-HFCE**
  - Refining:
    - Power @ $C42/MWh
  - Distribution & Retail:
    - NG@$C2.83/GJ

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**Note:** The costs are mid-point estimates and do not account for all factors affecting energy costs.
Diesel HDV’s account for 8% of Canada’s total GHG emissions

At current emission intensity, Alberta grid to battery electric has higher emissions than diesel incumbent.

Blue hydrogen can reduce emissions by ~81%
GOODNESS OF FIT COMPARISON

- Technology must meet the needs of the trucking sector
- Range, fueling time, and vehicle weight are important factors for many duty cycles
- Battery electric is likely not suitable for heavy payloads and long distance.
  - 800 kWh of batteries will have a range ~375km and add 6,500kg and 4 cubic meters of space

<table>
<thead>
<tr>
<th></th>
<th>Power, Torque, Driveability</th>
<th>Range &amp; Fueling Time</th>
<th>Tare Weight</th>
<th>Capital Costs</th>
<th>Maintenance Costs</th>
<th>Energy Costs</th>
</tr>
</thead>
<tbody>
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<td>☑️</td>
<td>☞</td>
<td>☝️</td>
<td>☐</td>
</tr>
</tbody>
</table>

- Better performance to the FD-ICE HDV
- Comparable performance to the FD-ICE HDV
- Underperforms to the FD-ICE HDV
- Relative performance uncertain at scale
Two HFCE Class 8 Trucks
- Heavy Weight (63.5 t gross) B-Train
- 700 km (Edm→Calg, return) between refueling
- Zero Tailpipe Emissions

Timetable:
- Design & Build: July 2019 to Fall 2021
- Test on Road: Fall 2021 to Spring 2023

H₂ Produced from AB Natural Gas:
- Steam Methane Reformed (no C mgmt.)
- Cascade Refueling

Industry Led
- By AB Carriers under real-world conditions
AN INDUSTRY-LED, $15M CONSORTIA SUPPORTED BY EMISSIONS REDUCTION ALBERTA WITH $7.3M.
Future of Freight C Energy System Impacts
ALBERTA IS IN THE TRANSPORTATION FUELS BUSINESS

WHAT IS THE OPPORTUNITY IN A NET-ZERO FUTURE?
2nd Generation Bio-based Diesel Resource Potential

- Sufficient resources to supply provincial heavy duty vehicle demand
- Insufficient resources to supply all diesel demand
- Cannot supply an export market
GRID POWER RESOURCE POTENTIAL

- Alberta grid load would increase by 25% to supply the trucking market; 66% for the whole diesel market.
- Doubling of the projected annual grid load growth rate to meet additional demand by 2050.
- Exporting to a market that is the same size of the current diesel market is not realistic.
- Alberta does not have a strong competitive advantage as a producer and supplier of low cost, low carbon electricity.
The potential provincial demand for hydrogen in Alberta’s freight sector is 1.4 Mt H₂/yr (55% of current H₂ production levels)

- 1.4 Mt H₂/yr @ $5/kg = $7 billion

To supply a North America market the same size as the diesel market is 13 Mt kt H₂/yr

- 13 Mt H₂/yr @ $5/kg = $65 billion
Blue Hydrogen Resource Potential

- Alberta has an abundance of natural gas
- Current production can easily supply the demand of the domestic and export freight markets
GREEN HYDROGEN SUPPORTING A LOW CARBON GRID

- Hydrogen and a low carbon grid are complementary
- Renewables used in public grid when power prices high
- Hydrogen produced when power prices low
- When conditions do not support renewable power generation- Oxy-fired NGCC with CCS is used

A. Allocation of Electricity Generation

B. Emissions Intensity of the Alberta Public Grid

- 719 kg CO₂e/MWh
- 270 kg CO₂e/MWh
GREEN HYDROGEN - RESOURCE POTENTIAL

- HDV hydrogen demand will increase grid by 150%, ~3700 4.8 MW wind turbines
- To support all demand - grid load would grow by 205%, ~6300 wind turbines
- A 9 times Alberta market size with green hydrogen would increase grid load by 11 times
GREEN HYDROGEN - RESOURCE POTENTIAL

What is reasonable?
Key Messages
The HDV transportation has high GHG emissions - the sector is poised for change.

Battery electric and hydrogen fuel cell electric are appealing zero emission options depending on the end-use duty cycle & grid intensity.

Hydrogen provides an opportunity for Alberta to remain a supplier of transportation fuels in a net-zero future.

Both blue and green hydrogen can be part of the transition pathway.
Questions?

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