



# Getting to Zero: A Road Less Paved

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# Where We Are Today

- Net-Zero is real

- *Canadian Net-Zero Emissions Accountability Act (2021): 2050*
- *2030 Emissions Reduction Plan (40%+, 2022)*

- \$400 million in additional funding for ZEV charging stations, in support of the Government's objective of adding 50,000 ZEV chargers to Canada's network.
- In addition, the Canada Infrastructure Bank will invest \$500 million in large-scale ZEV charging and refueling infrastructure that is revenue generating and in the public interest.
- \$547.5 million for a purchase incentive program for MHDVs. Purchase eligibility date will be announced in Budget 2022.
- \$199.6 million to retrofit large trucks currently on the road.
- \$33.8 million for hydrogen trucking demonstration projects that address barriers to long-haul zero-emission trucking commercialization – including technical, regulatory and standards challenges.
- \$2.2 million to support Greening Government fleet electrification commitments.

- MB: *Efficient Trucking Program (ETP), Canadian Agricultural Partnership (CAP), Canadian Green Ag Plan (under dev.)* – **only the beginning**

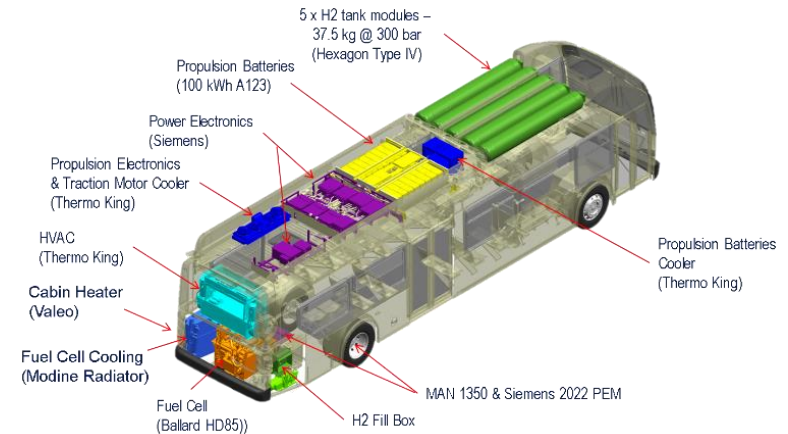
- The 2020s are not that great

- Fuel costs, inflation, labour shortages

- Status quo is attractive against challenges

# ZEV Technologies Are Here

- Electric Drivetrains
  - First generation: motors, power electronics, e-accessories
  - Next generation: electric chassis, e-axles, optimized components
- Batteries
  - Incremental energy density increases
  - Attn to heavy applications: cyclability
- Fuel Cells
  - Solution to highest energy, lowest flexibility applications
  - Fuel + e-drive
  - Modular to application, integrateable to BEV



## Disclosure: “zero”

- Zero or low at tailpipe
- Where is energy source ultimately derived?
  - Electricity mix
  - H2 colour
- “low carbon” preferred by stakeholders (except gov’t)



# Infrastructure

- Most difficult, most expensive
- Who owns responsibility for build-out?
  - ‘Depot’ applications
    - end user (to some extent)
  - ‘Disperse’ applications
    - Dedicated, distributed?
    - Industry shared?
    - Public/across industries/classes?
- Collective will needed to solve the infrastructure question
  - Funding issue crucial but not most important
  - “Right approach” (design, implementation, use) **the most critical**

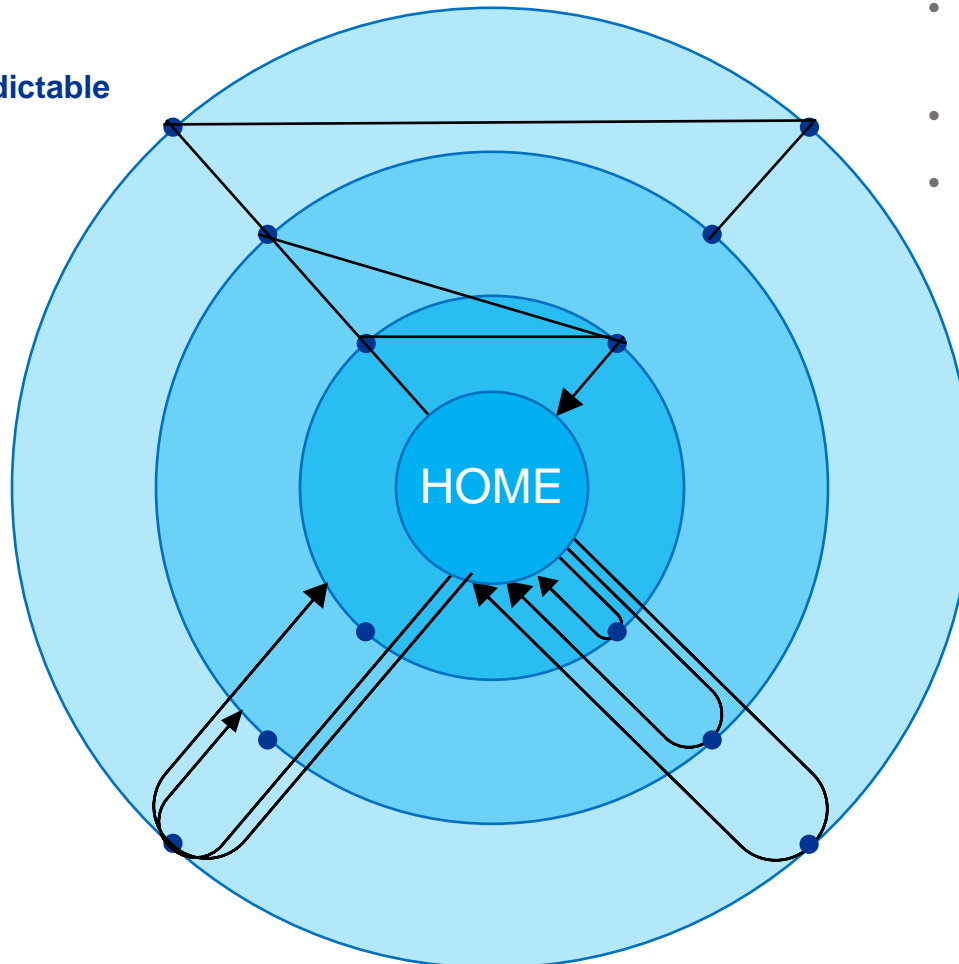
# Fleet Logistics with ZEVs

- How much does this change my MO?
- Factors:
  - Capex budget
  - Opex budget
    - Energy source cost
    - Maintenance costs
      - ~50% for BEV
- Energy
  - Deployment: adjust application to match capability
  - Replacement ratio: how many vehicles in my 100% ZEV fleet?
- Workforce
  - Operators
  - Technicians
  - Yard ops
  - Management and leadership



# Duty Cycles in MHDV

3. Various/flexible/unpredictable



2. Different destination

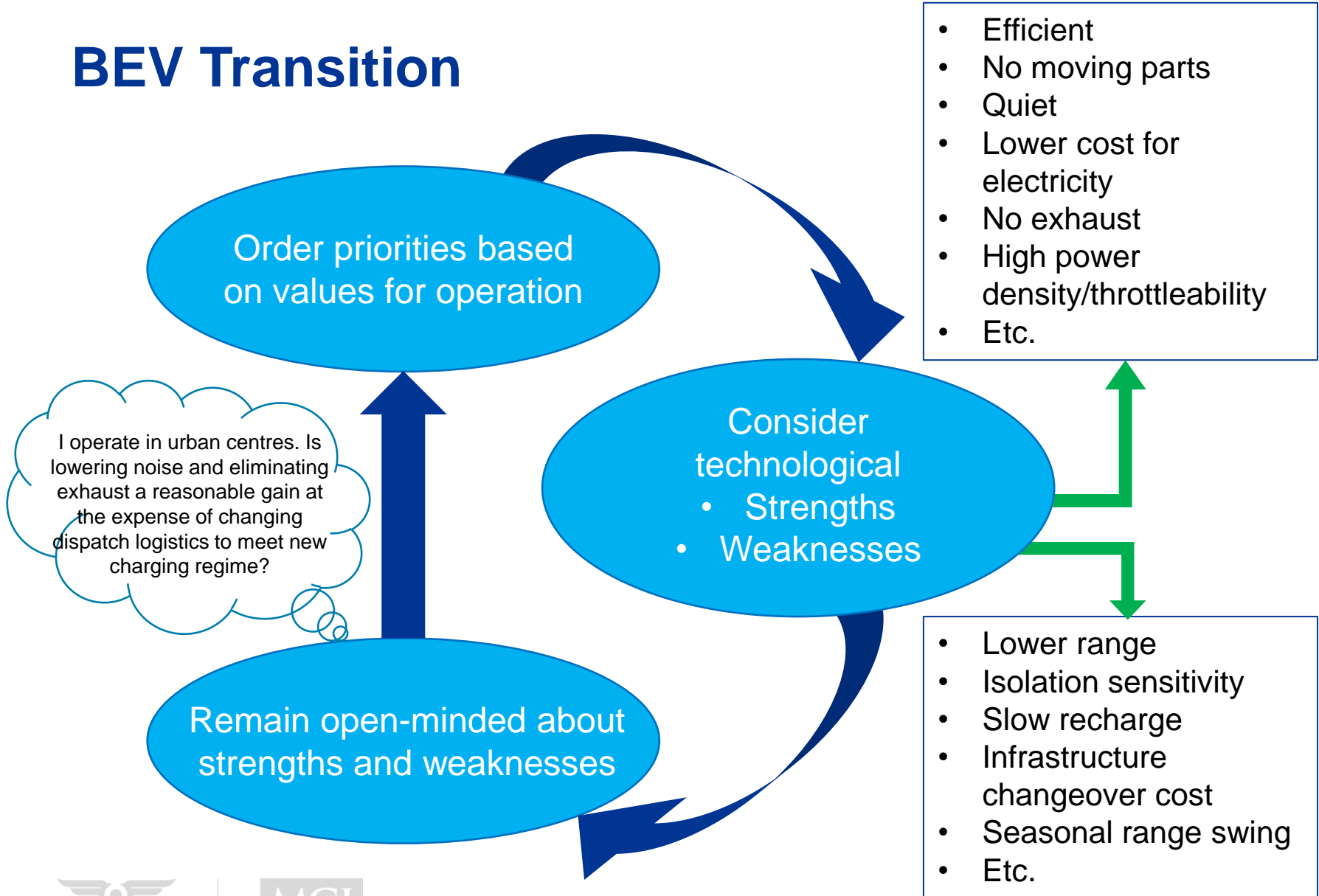
- Wide range packed into sector
- No 'one size fits all'
- Not shown: speed, load requirements

1. Come home everyday

# Consequences of Duty Cycles

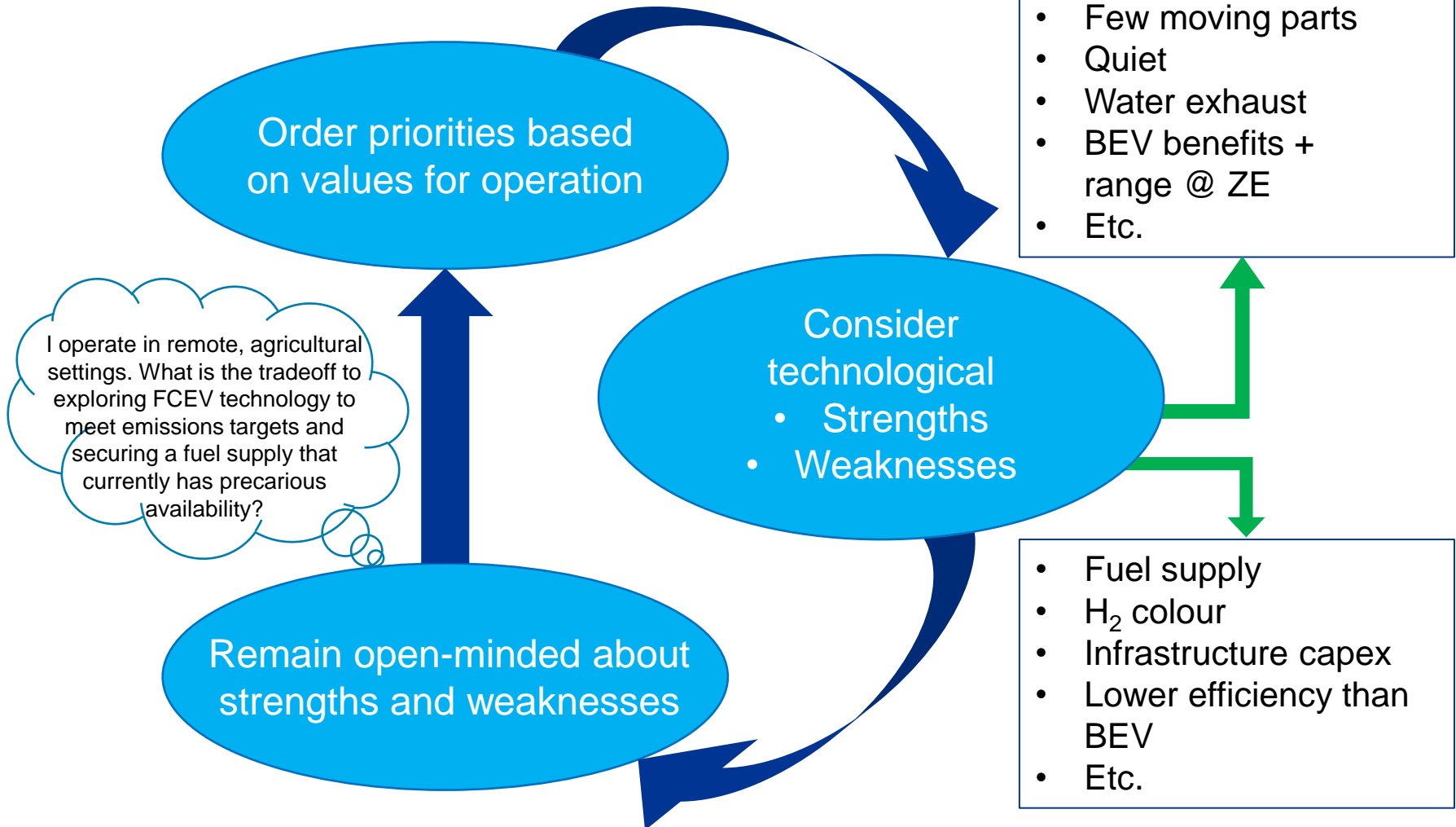
Duty Cycle	Propulsion	Infrastructure	Primary Stakeholder	Comments
1. "Home everyday"	BEV	<ul style="list-style-type: none"> <li>• Depot charging</li> <li>• On-route charging</li> </ul>	Operator owns infrastructure	Both LR ESS config & opportunity charging support
2. "Different destination"	FC-BEV	<ul style="list-style-type: none"> <li>• Remote charging</li> <li>• Depot H<sub>2</sub></li> <li>• Remote H<sub>2</sub></li> </ul>	Infrastructure co-owned	Minimize fuel costs, maximize range flexibility
3. "Full flex"	FCEV	<ul style="list-style-type: none"> <li>• Remote H<sub>2</sub></li> </ul>	Third party owns infrastructure	Weighted to FC over ESS, "run like diesel"

# BEV Transition





# FCEV Transition



# Reconciling Weaknesses

- Solutions are in the works

## BEV

- Lower range
- Isolation sensitivity
- Slow recharge
- Infrastructure changeover cost
- Seasonal range swing

Next-gen LIBs

Next-gen packaging

Dynamic charging, high power tolerance batteries, HV architecture, higher power chargers

Better playbook, smart charging

New HVAC, heat pumps, alternative heating

## FCEV

- Fuel supply
- H<sub>2</sub> colour
- Infrastructure capex
- Lower efficiency than BEV

New production, existing pivoting

MB Hydro, blue-ification of grey

Blueprints in development

Next-gen FCs

- Strategy: adopt/test/pilot technologies in the meantime

# 3. Other ZEV Transition

- HEVs, PHEVs, RE-BEVs
- CNG → RNG
- Diesel → Biofuels (EtOH mix, biodiesel, SAFs, methanol, etc.)
- H2 injection
- H2 ICE

Hydraenergy.com

Cummins.com



H2 gas handling components behind or under cab.



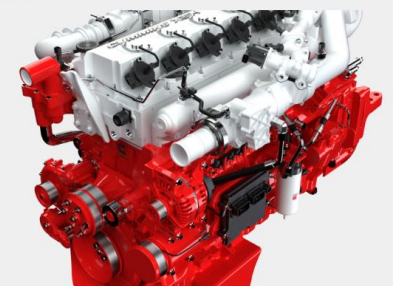
H2 injection manifold in-line with air intake blends H2 and air before entering engine block, **NO engine modification.**



Dedicated controller and wiring harness behind the dashboard (ECU), **NO interception/modification of OEM ECU messages.**

## CUMMINS INC. DEBUTS 15-LITER HYDROGEN ENGINE AT ACT EXPO

May 09, 2022 • Columbus, Indiana



Today, Cummins Inc. (NYSE: CMI) debuted its 15-liter hydrogen engine at ACT

Cummins Information

# Selecting Champions & De-Risking

- See table first. What's realistic?
- Preferences
  - Sometimes subjective
  - Available power sources
    - e.g. renewable grid
    - e.g. oil & gas sector
  - Gov't pressures
    - Favour economic sectors
- Be numbers-driven
  - Energy consumption & consumption rate
  - BOL vs EOL- usable vs nameplate
  - Seasonal impacts
- Energy demand
  - Distribution of charging: spread vs. peak
    - cost, stress on operator, pressure on infra
  - Economic interventions
    - tariffs, demand charges, other regs
  - Power banks as a solution
- Stakeholder involvement from the beginning
  - Utilities
  - Consultants
  - Academia
  - NGOs
  - Gov't funding

# The Path to Zero: Conclusions (so far)

- Asking the right questions is an easy but crucial first step
- Determine stakeholders & responsibilities
- Know the realities of your duty cycle
- Risk assessment on your champions
  - How far do I go right away? How far can I afford to go?
- Open-mindedness in status quo vs. new benefits of technology
- Be better, not perfect
  - Diesel heaters
  - Grey H<sub>2</sub>
  - Other transitional technologies
- Embrace the challenge



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