VOLVO GROUP TRUCKS H2 ICE

Why do we propose to develop H2 ICE engines and why now?

- The Volvo Group and its customers need low carbon transport solutions to meet Science Based Target initiative commitments as well as CO2 regulations
- H2 ICE offers advantages over diesel as well as current BEV and FCEV alternatives, particularly in the shorter term
- H2 industry being heavily promoted and subsidized to allow affordable clean H2 by 2030 (USA IRA + European Green Deal)
- H2 powered Internal Combustion Engines:
  - Builds upon existing industrial systems and provide -95% to -100% CO2 reduction tank to wheel during product life cycle.
  - Are well positioned regarding CO2 emitted during production

United States Environmental Protection Agency

SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

European Commission

Advantages of H2 ICE Technology

- Low CO2 – up to 100% reduction compared to diesel, low PM and considerably lower NOx than diesel
- Lower Capital Cost than BEV, FCEV
- Less impact to payload and/or chassis space
- H2 infrastructure benefits both H2 ICE and FCEV vehicles

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The four zero-emissions technologies have advantages and disadvantages.

Variations across categories — High performance | Medium-high | Medium-low | Low performance

	Bio/synfuel	Hydrogen internal combustion engines (H2-ICE)	Hydrogen (H2) fuel cell	Battery electric
Emissions				
CO_2 intensity	CO_2 intensity depends on source of biomass/carbon	Zero/minimal CO_2 if using green/blue H2	Zero/minimal CO_2 if using green/blue H2	CO_2 intensity depends on grid mix; zero CO_2 if using renewable power
Air quality	NO_x[1] and particulate matter emissions similar to diesel	No significant NOx emissions with SCR[2] aftertreatment	Zero emissions	Zero emissions
Total cost of ownership				
Efficiency (well-to-wheel)	~20%	~30% for renewable H2 production	~35% for renewable H2 production	75–85%+ depending on transmission and charging losses
Powertrain capital expenditure	Same as today's combustion engines	H2 engine with similar capex as diesel ICE, but H2 tank required	High capex for fuel cells and batteries, but more scalable than BEV[3]	High capex if large batteries required (medium for smaller/ lighter segments)
Constraints (space/payload)	Same size and weight as today's combustion engines	Engine with same size as today, but H2 tank needed	More space needed than combustion engine for fuel cell and H2 tank	Higher weight than combustion engine; payload constraints subject to use case
Uptime/refueling	<15 minutes, depending on tank size	<15–30 minutes, depending on tank size	<15–30 minutes, depending on tank size	3+ hours, depending on ability for fast charging
Infrastructure costs	Can use existing infrastructure	H2 distribution and refueling infra-structure required	H2 distribution and refueling infra-structure required	Charging infra-structure and grid upgrades required

[1]Nitrogen oxides.
[2]Selective catalytic reduction.
[3]Battery electric vehicle.

McKinsey & Company

June 2021 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-hydrogen-combustion-engines-can-contribute-to-zero-emissions

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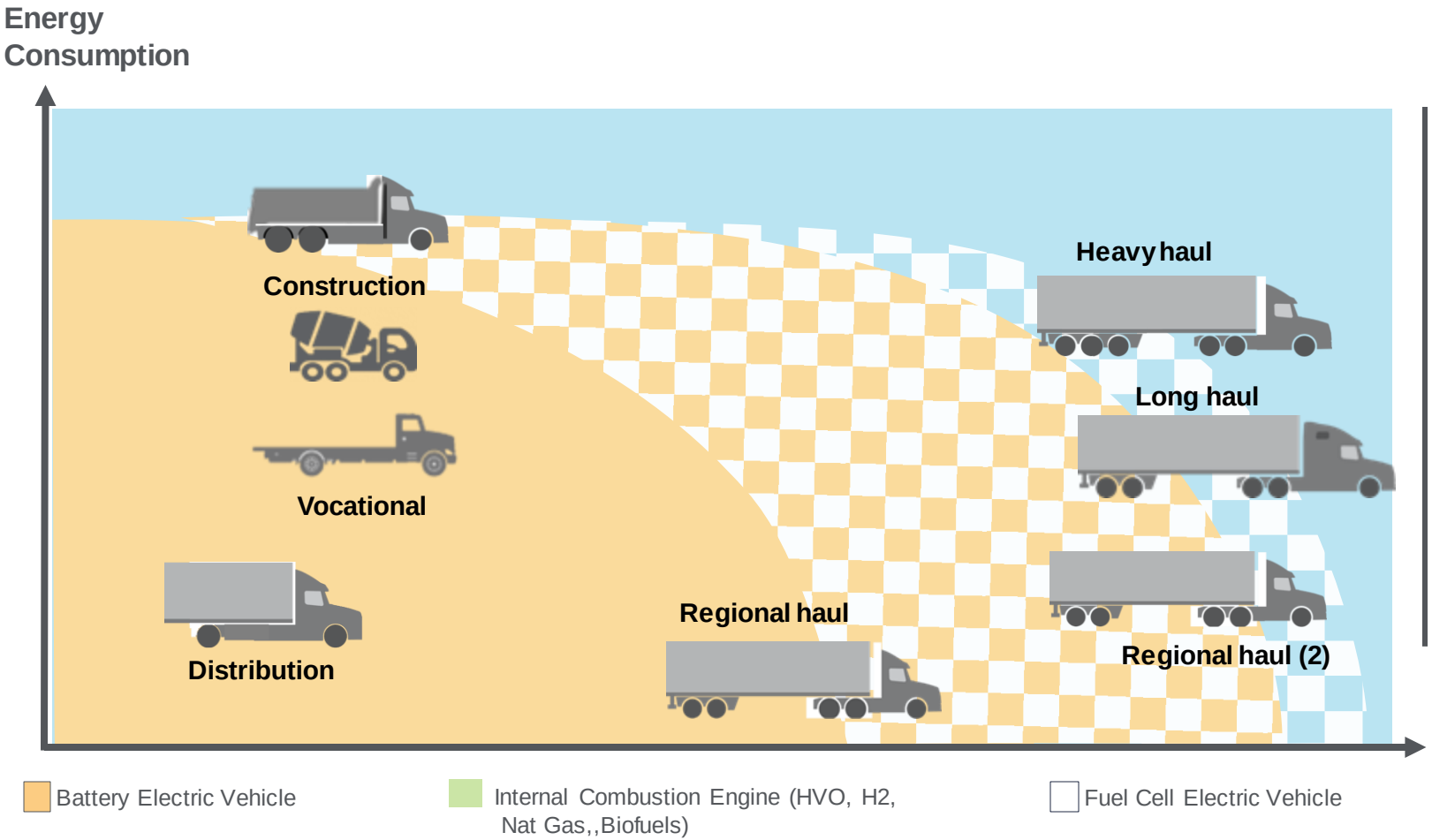
ZEV Technology adoption ~2030



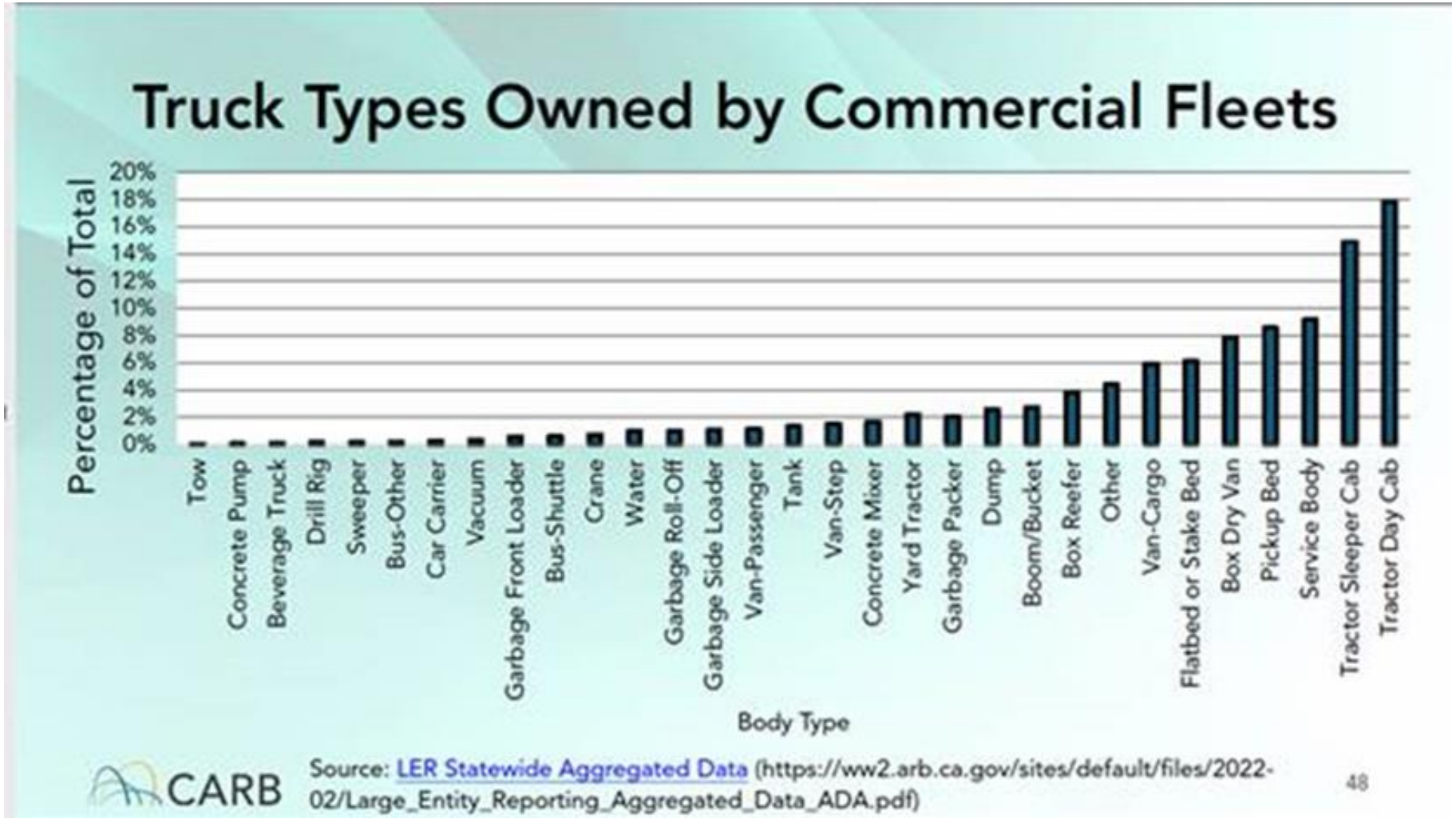
Wide range of applications

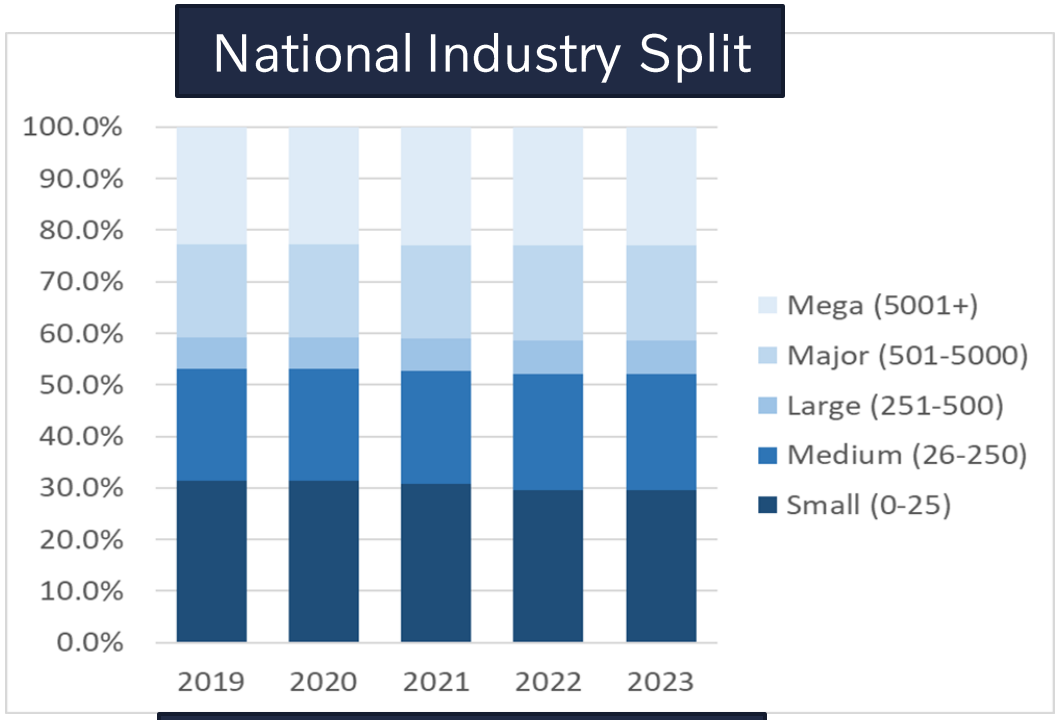
- Available technologies can address transport needs in several segments

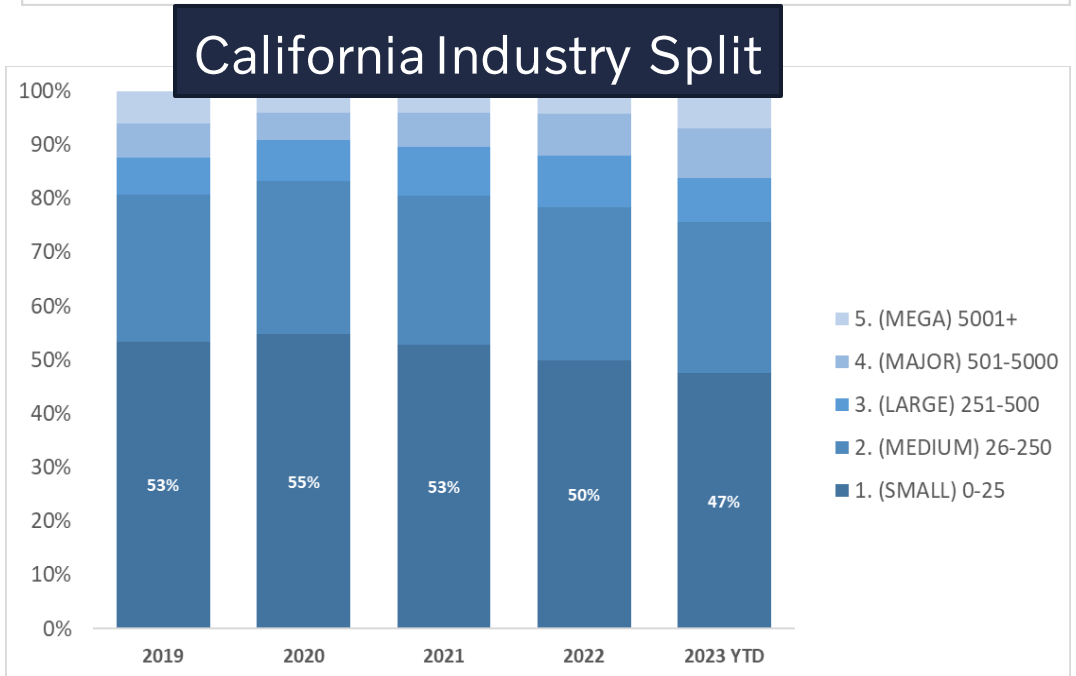
Business viability for the technologies in each market is set by:

- Total operational cost
- Infrastructure for Electricity vs Hydrogen

No single solution fits all customers in CA
Multiple Solutions are Required, H2 ICE can be one







California has a significantly greater percentage of smaller fleet operators (by Registration in CA)

Small and Medium fleets make up:

- Approx 50% of national fleets
- Approx 80% of CA fleets

Smaller fleets are generally more affected by:

- Higher vehicle costs
- Charging infrastructure challenges
- Financing availability
- TCO sensitivity

Summary

- With the current ACT regulation:
  - No combustion engine vehicle can count towards ACT sales %
  - Solutions that can reduce NOx and emit low/no CO2 are being excluded
  - Risk that diesel sales need to be limited to stay in compliance if not enough ZEVs are sold
- Allowing H2 ICE to be counted as a ZEV will provide:
  - an alternative avenue for customers to reduce emissions and meet their corporate carbon footprint goals
  - a lower emitting vehicle option with less weight and/or more space for packaging
  - a lower initial purchase price which will facilitate fleet turnover and regulatory compliance
  - quick refueling times which can help extend range
  - a TCO that will improve as H2 price improves
  - additional H2 demand to accelerate the H2 infrastructure for improved FCEV penetration

- H2 ICE can help accelerate alternative vehicle adoptions and should be considered as a viable solution for ACT ZEV compliance