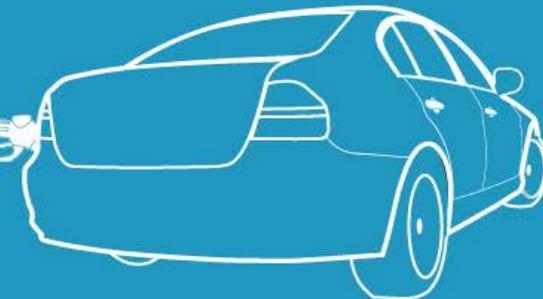
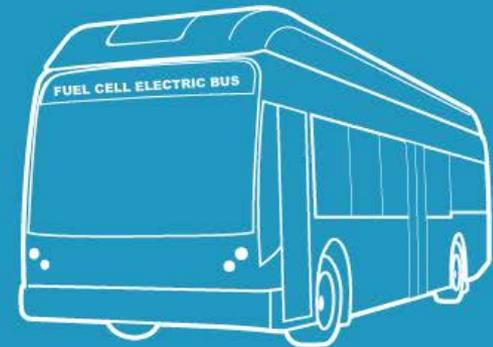


# MD/HD Fuel Cell Trucks *Demonstrations First*

Nico Bouwkamp

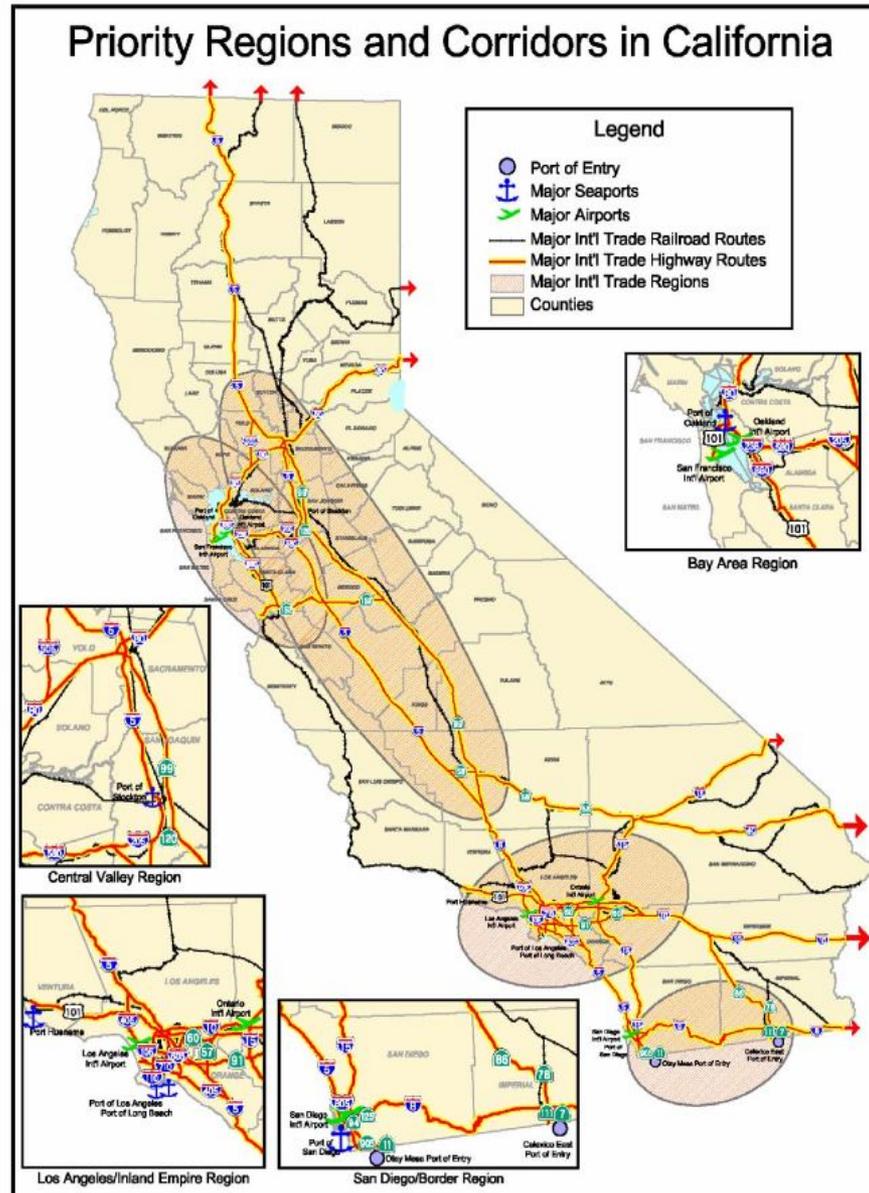
Emerging Truck Technologies Workshop - ITS UC Davis

December 3, 2015





# Snapshot of California



Source: CARB



# Context for Fuel Cell Trucks

- CARB: Sustainable Freight Strategy
  - Zero and near-zero trucks
  - Mandate not in place, but imminent (?)
- CA Governor executive orders for GHG reduction
- US EPA: Emission reduction
  - Phase 2 coming
- CARB AQIP/GGRF and CEC AB8 funding
  - FCEB project (New Flyer/Hydrogenics)
  - ZE truck projects, including HD FCEVs



# Vehicle Categories by Usage

## Class 7/8 Tractors



Over the Road

- Younger Trucks; High Annual VMT
- Mostly higher average speed, highway driving



Short Haul/  
Regional

- Between cities; Drayage; Day Cabs
- Includes second use trucks; trucks with smaller engines

## Class 3-8 Vocational Work Trucks



Urban

- Cargo, freight, delivery collection
- Lower VMT; Lower Average speed; Lots of stop start



Rural/  
Intracity

- Cargo, freight, delivery collection
- Higher VMT; Higher Avg speed; Combined urban/ highway



Work site  
support

- Utility trucks, construction, etc.
- Lots of idle time; Lots of PTO use

## Class 2B/3



Pickups/  
Vans

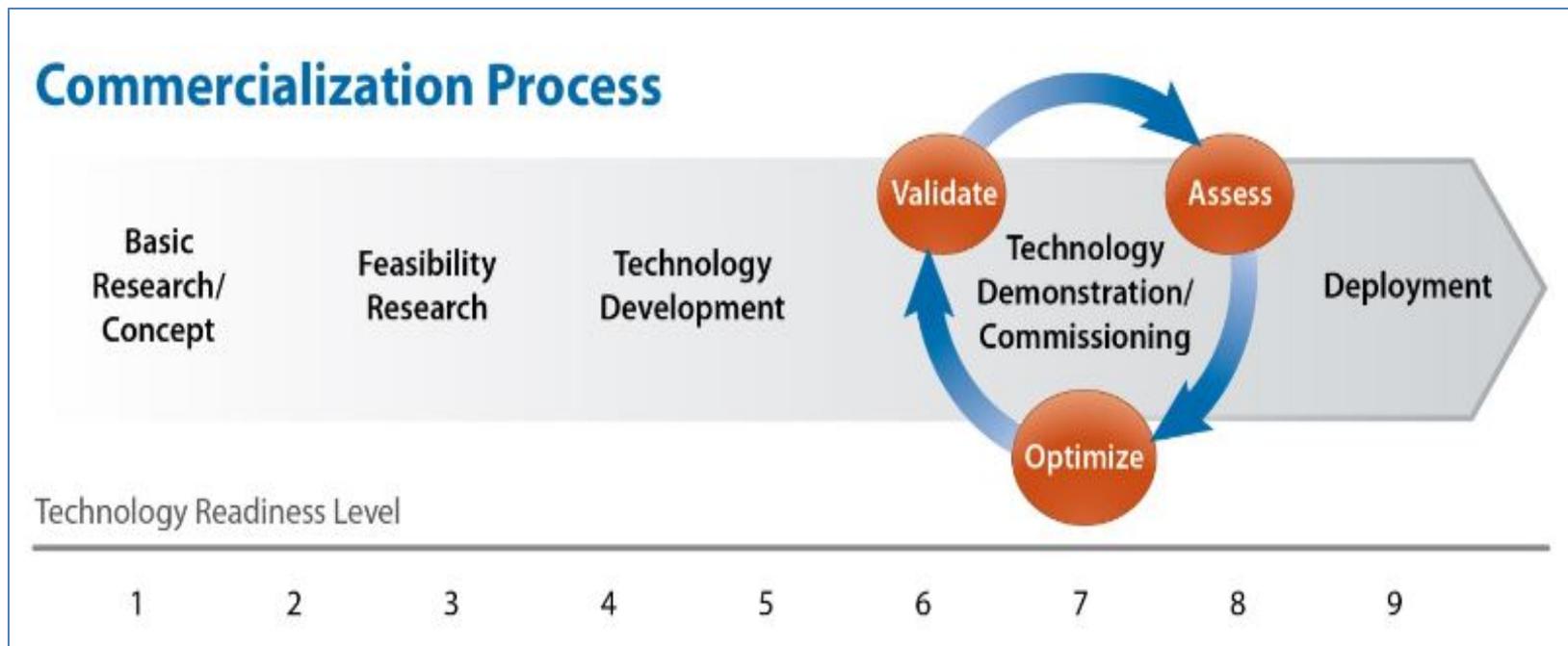
- Commercial use; Automotive OEMs & volumes

Source: CalHEAT



# Technology Readiness

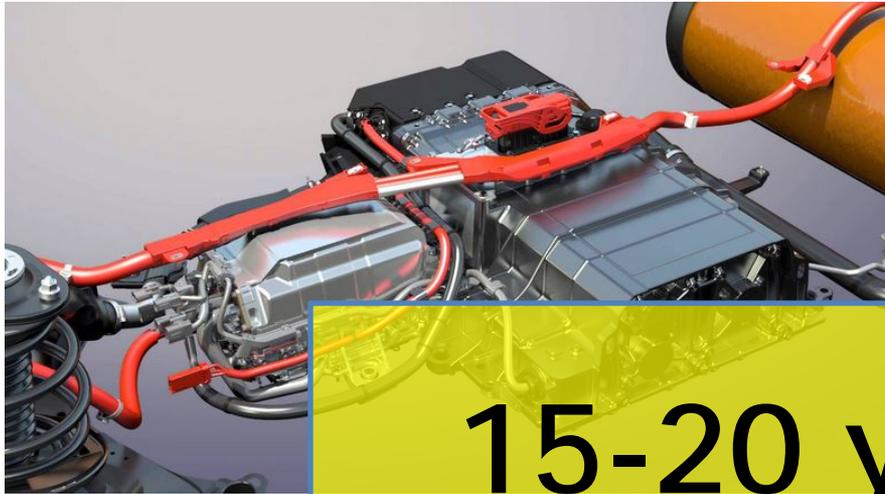
- Measure towards commercialization
- Not a market sustainability indicator
- Not equal indicator for both MD and HD trucks
- Not indicator for supporting fueling infrastructure



Source: NREL



# LDV FC Systems Commercialization



Source: Toyota



Source: Hyundai

**15-20 years of development**



GM Project Driveway Fuel Cell Powercube

GM Next Generation Fuel Cell Powercube

Source: GM



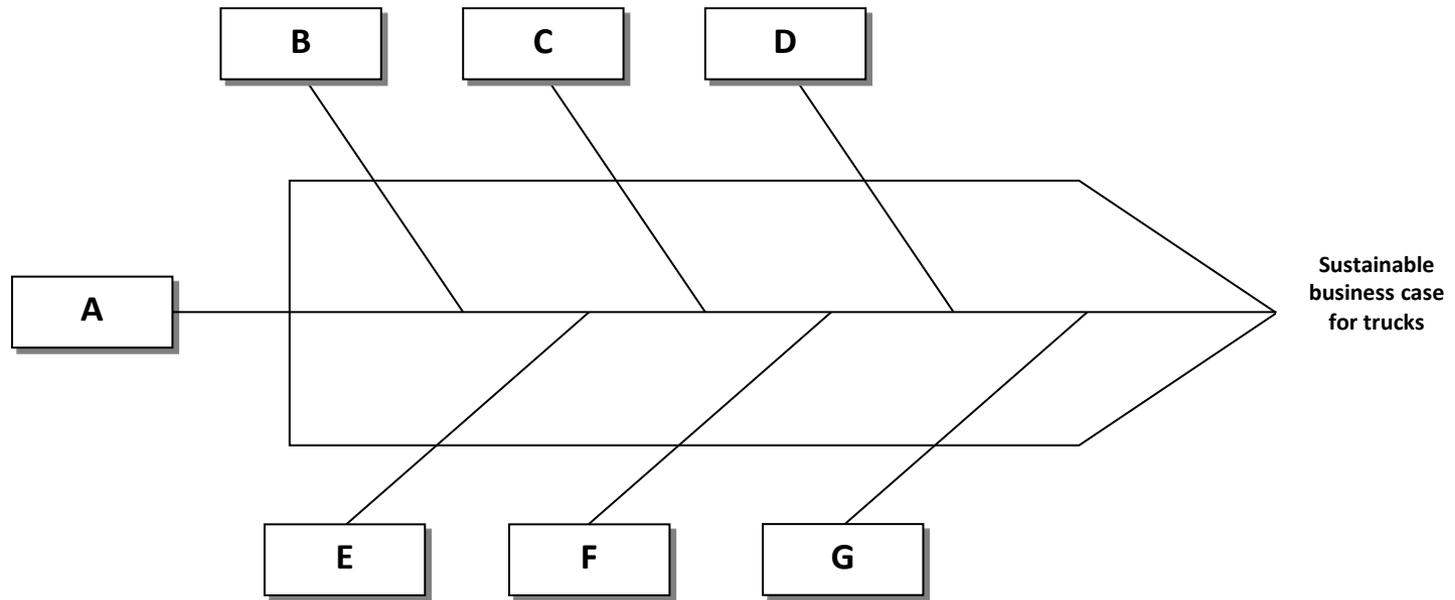
# FC Truck Configurations

- Fuel cell systems: 30 - 100 kW
  - Ballard, Hydrogenics, US Fuel Cell
- Battery systems: 26 - 125 kWh
  - N/A
- Hydrogen storage capacity
  - 20-30 kg (@35MPa)
- Configurations
  - Plug-in battery dominant fuel cell range extended
  - Battery dominant fuel cell charge sustaining
  - Fuel cell system dominant hybrid battery
- Involved companies
  - HD: BAE Systems, PACCAR, Powerdisc, Siemens, Transpower, US Hybrid
  - MD: UoT Center for Electromechanics, EVI, PlugPower, Hydrogenics

- *For comparison - 40' fuel cell transit buses*
  - Fuel cell systems: 80-150 kW
  - Battery systems: 11-47 kWh
  - Hydrogen storage capacity: 30-50 kg (@ 35MPa)



# Business Case for FC Trucks



- A.** Meets customer requirements
- B.** Favorable operating environment
- C.** Regulatory stability for product planning
- D.** OEM essentials
  - i.** Essential enablers
  - ii.** Revenue to sustain operations
  - iii.** Return on investment + profit

- E.** Incentives support the path to sustainable sales
- F.** Accessible and affordable fueling
- G.** Go/no-go milestone



# What's Needed First?

- Demonstrations first to collect operational data
  - Limited information available to make long term decisions
  - No California mandate or requirement currently in place
  - Duty cycle and market definitions needed
- Facilitate transfer of knowledge
  - Experience with fuel cell bus technology
  - Experience with passenger FCEVs
  - Experience with FC shuttle buses
- Study the business case (OEMs, users/operators/infra)
  - Identify barriers for adoption (for OEM, user, infra)
- The right cost targets
- Consistent long term policy and funding



# Questions or comments?

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# Vehicle Targets (Class 4-6 Parcel Delivery)

Parameter	Minimum requirement for MD FC package delivery truck	Gasoline or CNG package delivery truck benchmark
Range per fueling	> 125 miles (daily)	400 miles (before refueling)
Performance	0-60 MPH in 26 sec (for Class 5)	0-60 MPH in 12 sec
Top speed	65 MPH	85 MPH
Refueling interval	1 day	Multiple days, depending on duty cycle and 400 miles range
Operating time per day	12 hrs	14 hrs
Flexibility to assign to a subset of routes	95%	100%
Gradability	5% - launch to top cruising speed of 30 MPH in 7 sec 10% - launch to top cruising speed of 20 MPH in 2 sec 15% - launch to top cruising speed of 20 MPH in 3 sec	
Durability – miles	TBD	300,000 miles
Durability – hours	> 5000 hrs	
Durability – years	10-12 years	22 years
Uptime/availability	95% (5% scheduled maintenance)	≥98%
Warranty	TBD	3 yrs/50,000 miles



# Vehicle Targets (Class 7-8 Drayage)

Parameter	Minimum requirement for HD FC drayage truck	Diesel drayage truck benchmark
Range per fueling	>100-200 miles (daily)	400 miles (before refueling)
Performance	1,200-1,800 ft-lbs of torque	400 HP/1,200-1,800 ft-lbs of torque
Top speed	62-65 MPH	62-65 MPH
Refueling interval	1 day	2-4 days
Operating time per day	10-14 hrs	10-14 hrs
Flexibility to assign to a subset of routes	“Full service”	“Full service”
Gradability	6.5%	6.5%
Durability – miles	~500,000 miles	~500,000 miles
Durability – years	≥8 years	≥10 years
Uptime/availability	≥90%	≥90%
Warranty	3 yrs/300,000 miles	3 yrs/300,000 miles

Source: CALSTART