Kenworth Electrified Powertrain

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PANY

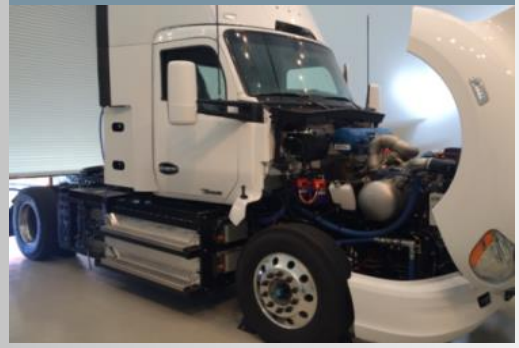
KENWORTH Electrification History

2008 – MD Parallel Hybrid Production

2008 – HD Parallel Hybrid Demonstration

2012 – MD Micro-Turbine Series Hybrid

2015 – HD Micro-Turbine Series Hybrid



2018 – Fuel Cell and Nat Gas Hybrid

Industry Outlook 2030 – Trucking Industry

Line Haul

- Advanced Aero Cab
- Diesel Mild Hybrid and Fuel Cell EV
- Autonomous Level 4+

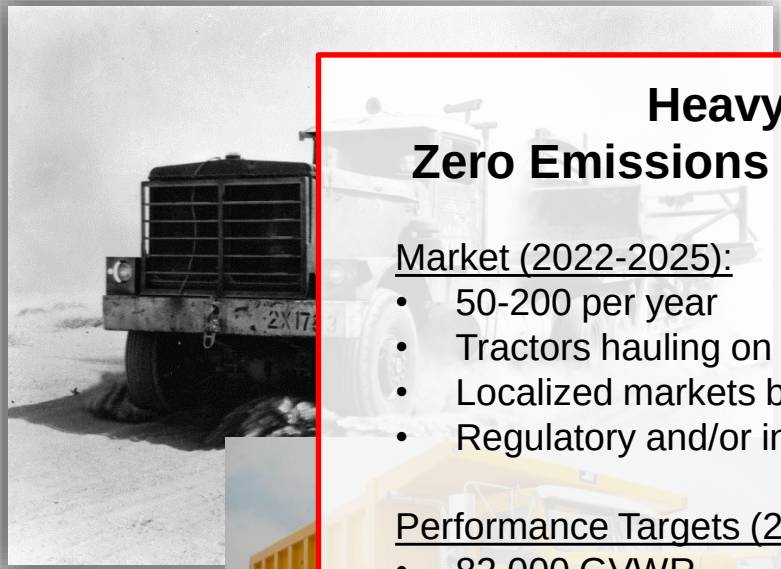
Regional Haul

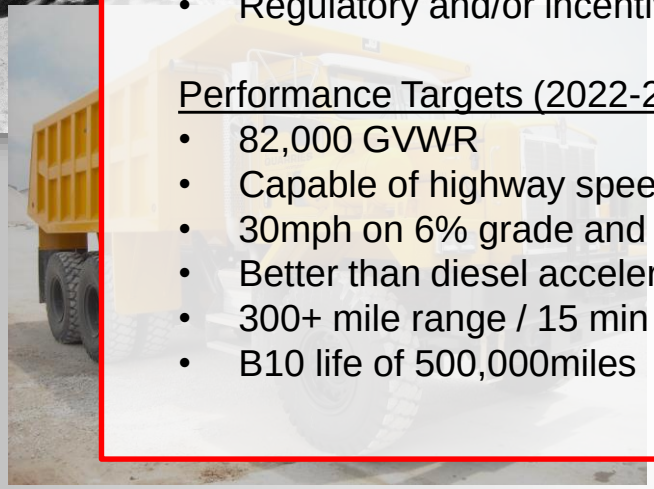
- Day Cab
- Diesel Hybrid / BEV / Fuel Cell EV
- Autonomous Level 4+

Urban Delivery

- MD / Step Van / Pod
- Diesel Hybrid and BEV
- Autonomous Level 4-5

KENWORTH – Built for the Job





Heavy Duty Tractors with Zero Emissions and Zero-Emission Capability

Market (2022-2025):

- 50-200 per year
- Tractors hauling on regional routes
- Localized markets based on infrastructure
- Regulatory and/or incentive driven

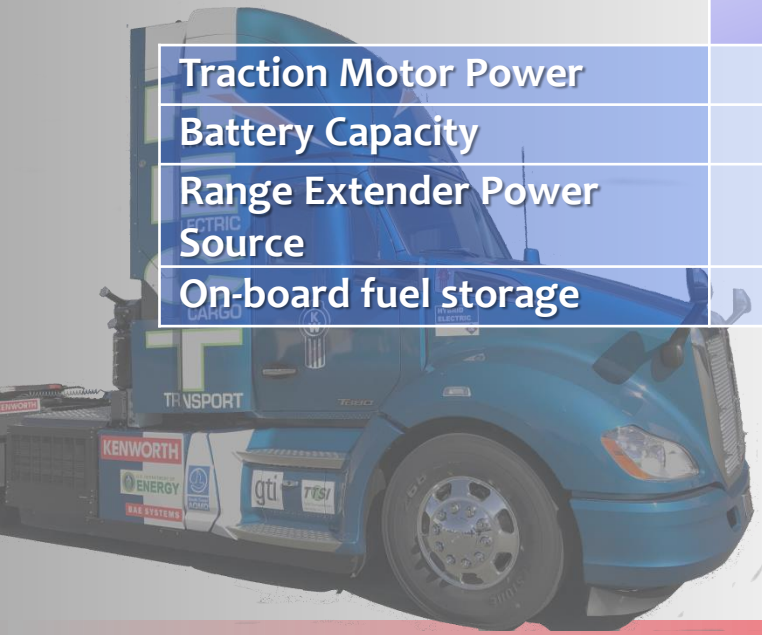
Performance Targets (2022-2025):

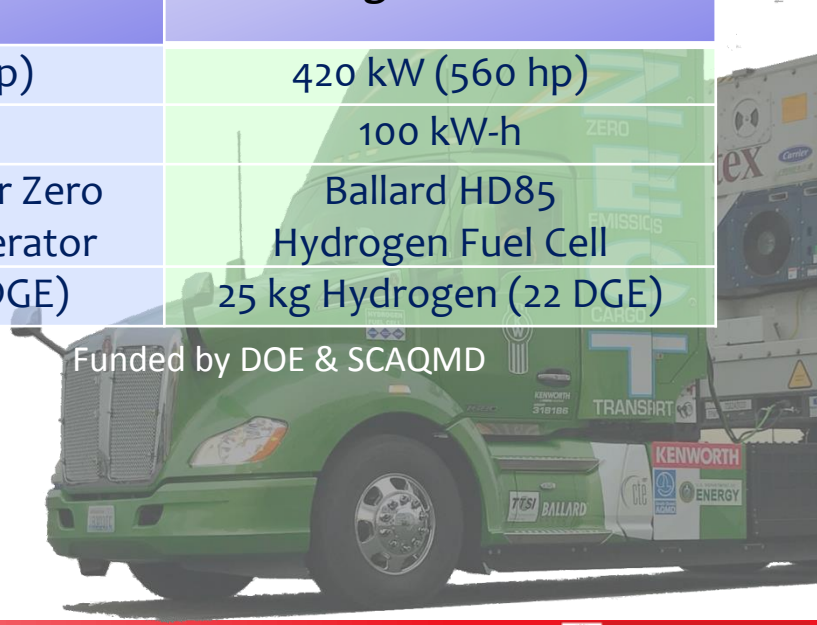
- 82,000 GVWR
- Capable of highway speed operation
- 30mph on 6% grade and startability on 20% grade
- Better than diesel acceleration 0 - 30mph
- 300+ mile range / 15 min refill
- B10 life of 500,000miles

Kenworth Electrified Powertrain Projects

	Battery Electric with CNG Range Extender	Battery-Electric with Hydrogen Fuel Cell Range Extender
Traction Motor Power	420 kW (560 hp)	420 kW (560 hp)
Battery Capacity	100 kW-h	100 kW-h
Range Extender Power Source	Cummins L9N Near Zero CNG Engine / Generator	Ballard HD85 Hydrogen Fuel Cell
On-board fuel storage	130 kg CNG (45DGE)	25 kg Hydrogen (22 DGE)

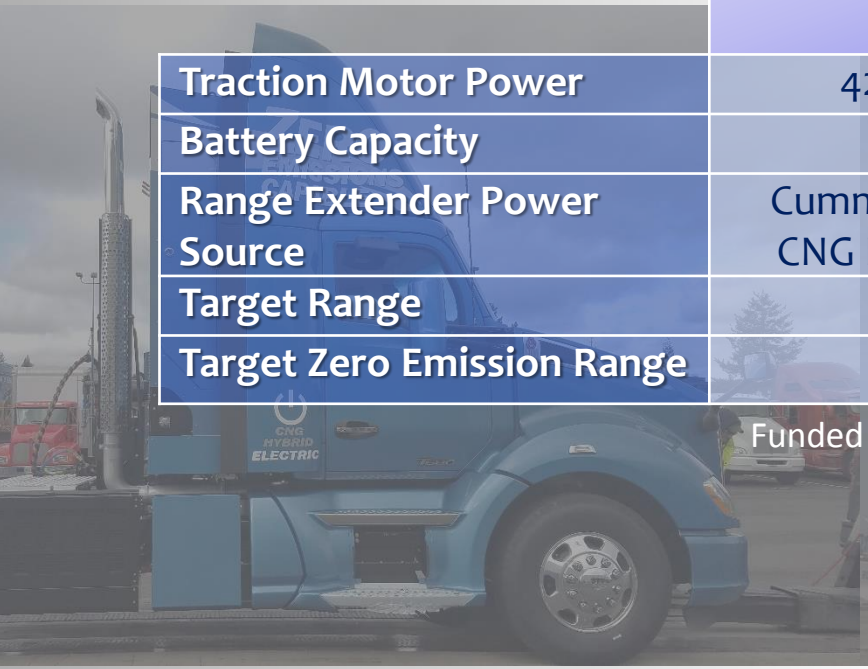
Funded by DOE & SCAQMD

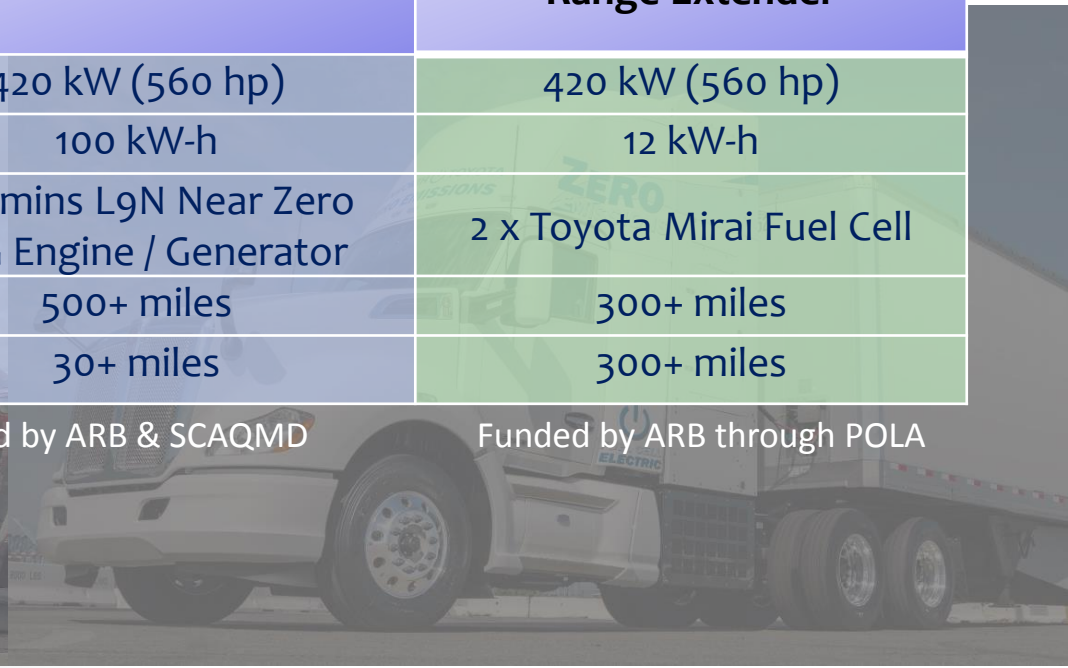




KENWORTH Electrified Powertrain Projects

	Battery Electric with CNG Range Extender	Battery-Electric with Hydrogen Fuel Cell Range Extender
Traction Motor Power	420 kW (560 hp)	420 kW (560 hp)
Battery Capacity	100 kW-h	12 kW-h
Range Extender Power Source	Cummins L9N Near Zero CNG Engine / Generator	2 x Toyota Mirai Fuel Cell
Target Range	500+ miles	300+ miles
Target Zero Emission Range	30+ miles	300+ miles
	Funded by ARB & SCAQMD	Funded by ARB through POLA





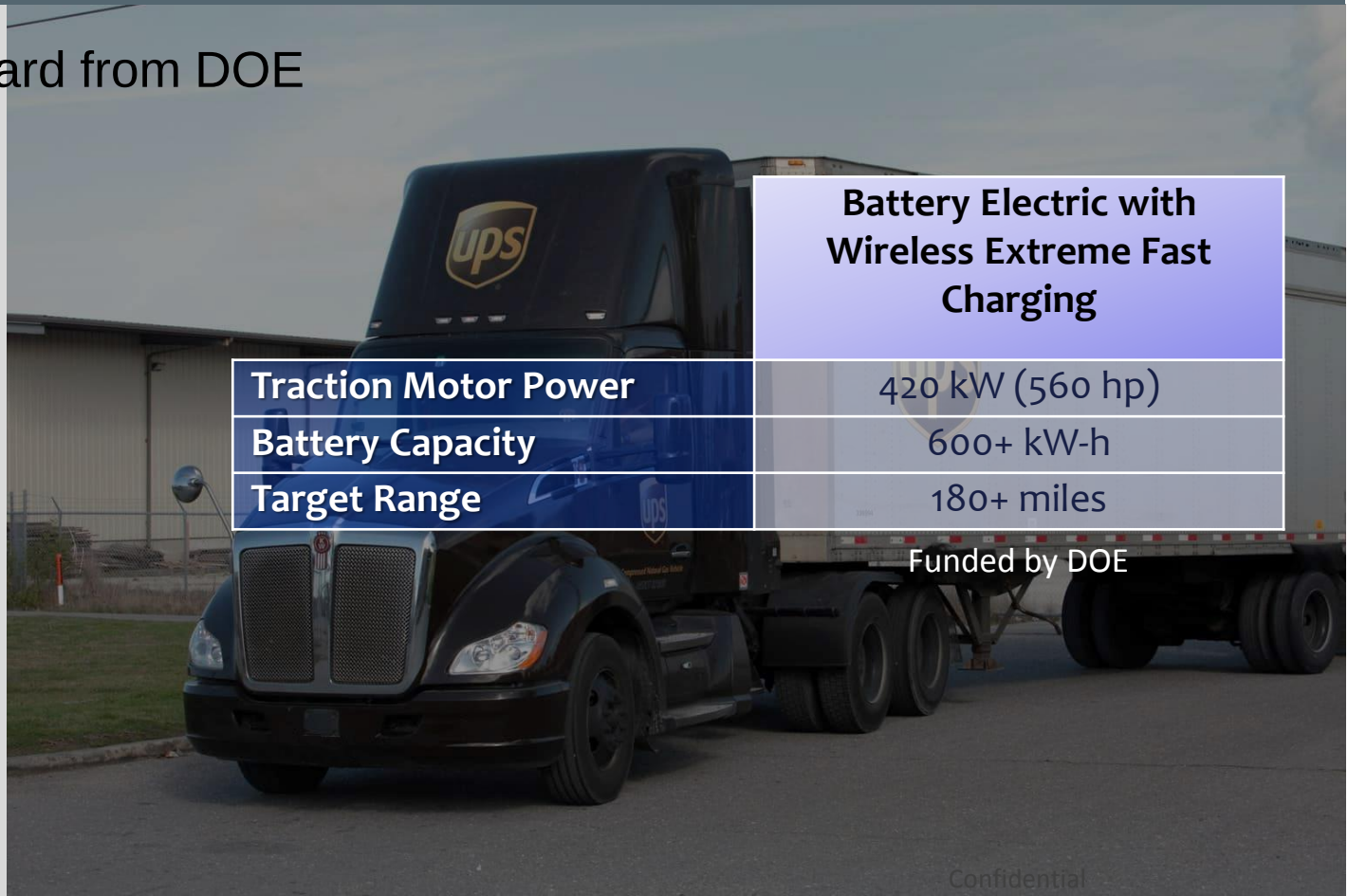
Kenworth – Toyota

Partnership Responsibilities

- **Toyota**
  - Fuel Cells Stacks
  - Balance Of Plant
  - Power Delivery Controls
  - Hydrogen Fuel Storage
  - Batteries
- **Kenworth**
  - Chassis and Cab
  - Supervisory Controls
  - Motors and Transmission
  - Cooling Systems
  - Integration

KENWORTH Electrified Powertrain Projects

Recent Award from DOE



	Battery Electric with Wireless Extreme Fast Charging
Traction Motor Power	420 kW (560 hp)
Battery Capacity	600+ kW-h
Target Range	180+ miles

Funded by DOE

KENWORTH Electrified Powertrain Projects

Recent Award from DOE

- Long-Range Battery-Electric Tractor-Trailer
- Local routes during day shift
- Night shift:
  - Seattle to Portland
  - Re-charge in Portland in 30 minutes
  - Return to Seattle
- Wireless charging at Megawatt rate
- Project start planned for 1 October 2019
- Commercial operation planned January 2021

Challenges for Adoption

- Developing Supply Base
- Complex Cooling and Electrical Architectures
- Driver Interface Needs Are Critical
- High Customer Interest at Limited Scale
- Need Continuous High Power Output for Long Grades
- Fueling Infrastructure
- Fuel Cell Cost


KENWORTH TOYOTA
ZERO EMISSIONS
ZERO
EMISSIONS
FUEL CELL
ELECTRIC