

# APTA 2017 Bus & Paratransit Conference

## Buying New buses? Electric? Hybrid? How Do You Decide What's Best for Your Agency?

### Extending Electric Range with New Hybrid Technology

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## We help cities **electrify** transit

- Leading **manufacturer** of series electric propulsion systems – **US made**
- More than **7,000 hybrid buses** in service today on five continents
- More than 2 billion revenue miles
- Prevented **2 million tons of CO<sub>2</sub> emissions**
- Demonstrating **20 zero-emission buses today**
- Developing innovative **conventional propulsion** bus and coach **electrification** solutions



**IVECO**

**GILLIG**

**NEW FLYER**

**SOLARIS**

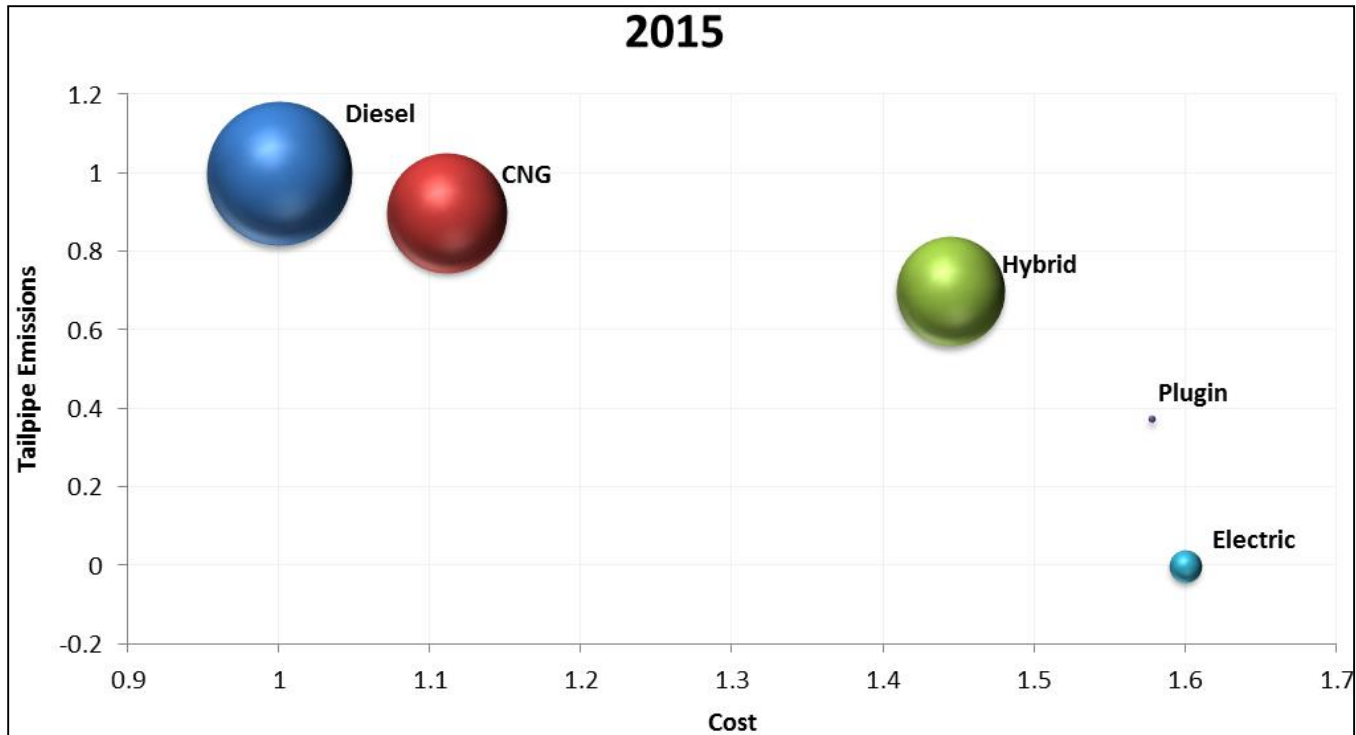
**NOVABUS**  
Driven by your city

**ALEXANDER DENNIS**

**DAIMLER**

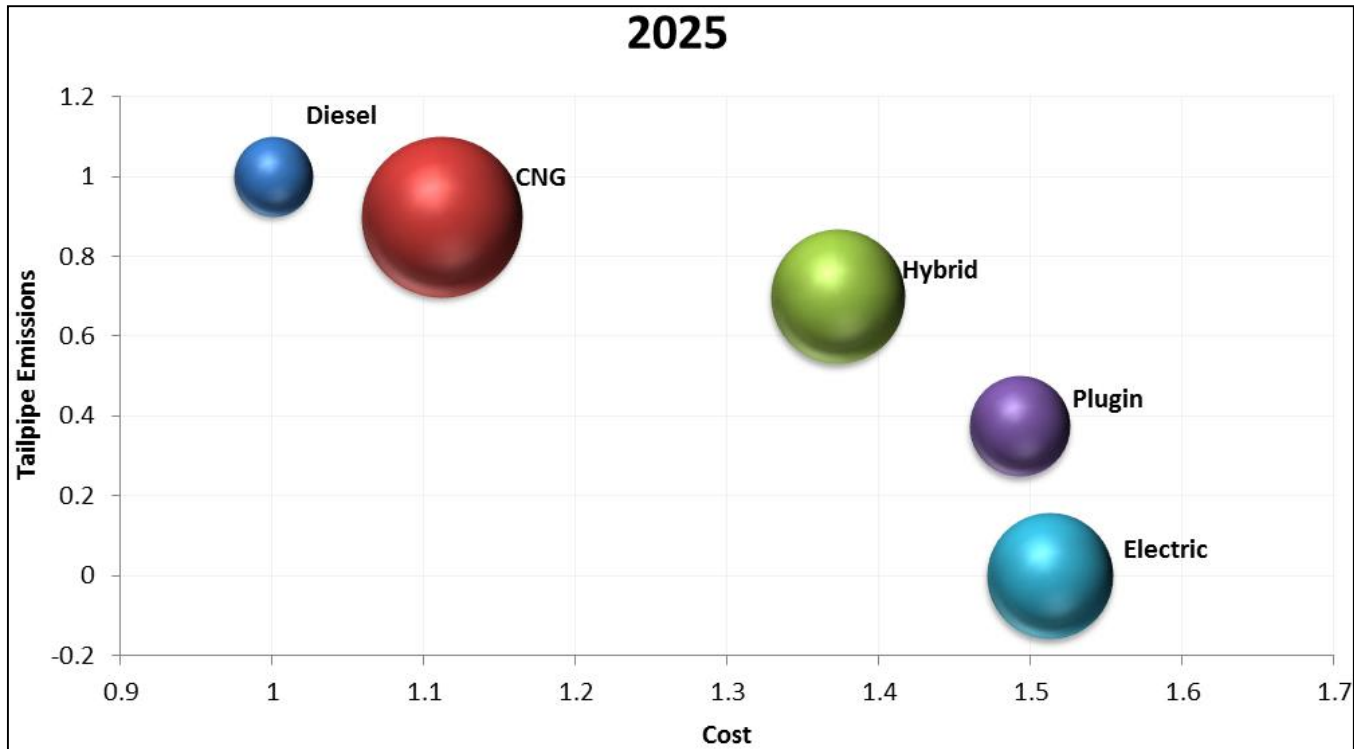
**ElDorado National**

# Market Forecast - North America Transit Bus



Data from Oct 2016 Frost & Sullivan report

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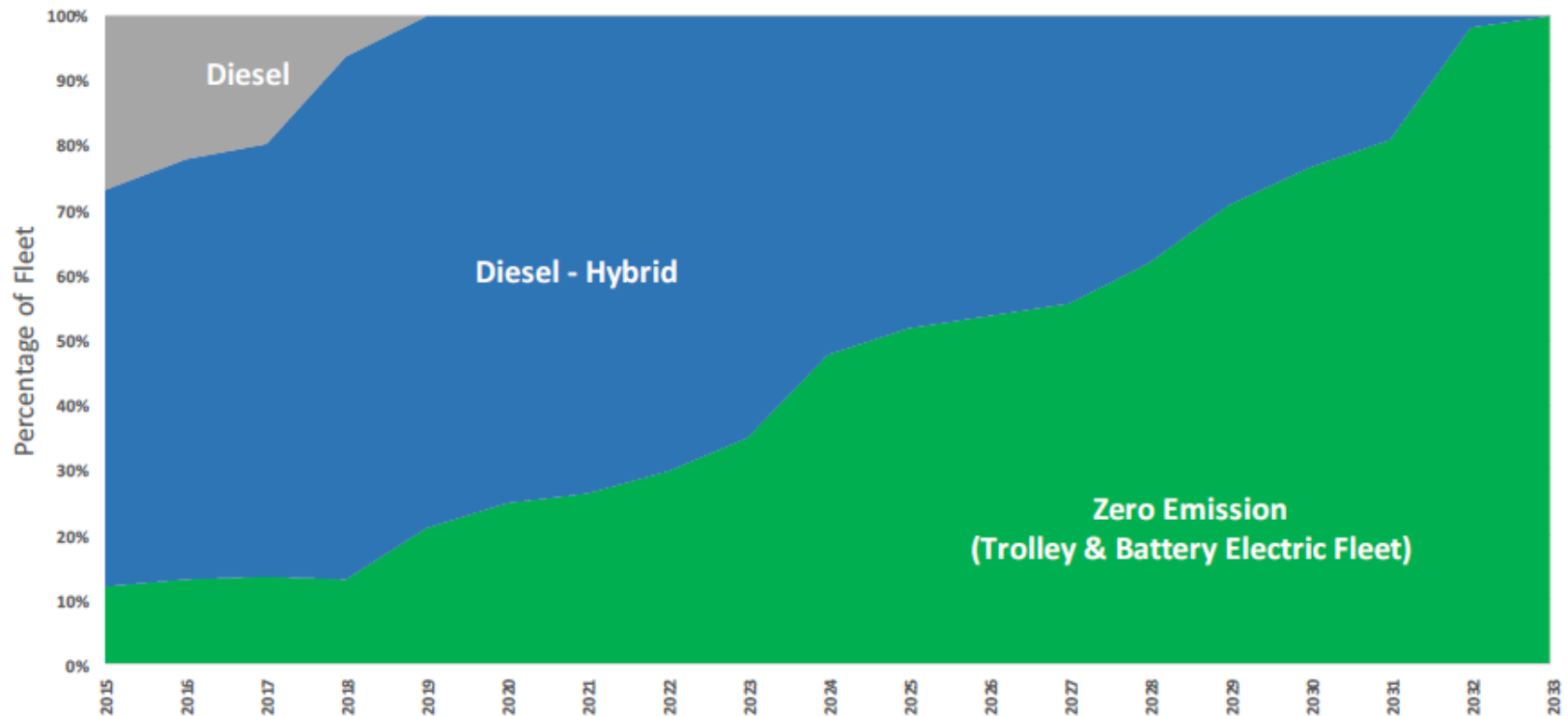
# The end state: **no emission**

Zero-emission, battery-electric & fuel cell programs



But, It won't happen overnight . . . . Seattle's plan  
**Fielding "low" . . . to get to "no"**

Figure 9: Fleet Replacement Plan: Potential for Zero-Emission Fleet



Source: King County Metro, Feasibility of Achieving a Carbon-Neutral or Zero-Emission Fleet (March 2017)

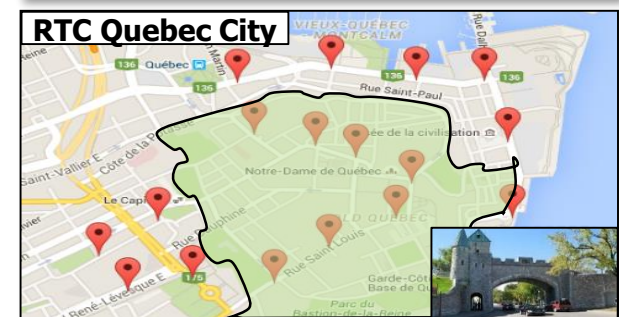
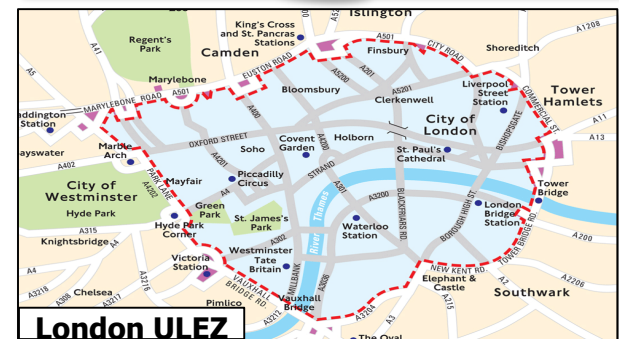
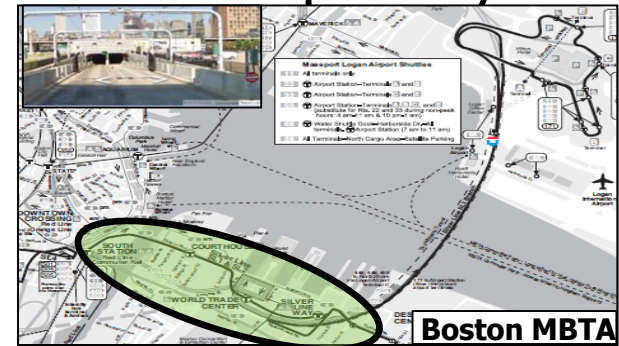
## Why is the **transition period** a likely scenario?

- EVs are still a bit of a conundrum
- Range (size/weight/capacity of battery) and anxiety
  - Total Revenue Service Energy : 1.9-2.9 kWh/mi (duty-cycle & accessory load dependent)
  - Installed battery capacity for 130 mile range:
    - 386-589 kWh (assumes 80% usable, 80% EOL capacity fade)
    - 309-471 kWh BOL (80% usable, 80% EOL range decrease to 104 mi)
    - Larger than most buses can support (wo/sacrificing passenger capacity)
- Charging infrastructure (scalability)
  - On-route charging solves the bus level battery size/capacity issues
  - Cost and logistics (real estate, substations, construction and traffic disruptions, the power grid itself, etc.) to implement on-route charging stations en-masse for a large fleet of buses in an urban area is not terribly clear
  - A depot of 200 EV buses will consume 55-84 MWh of power each day
  - Overnight charging evenly over 10 hour period requires 5.5-8.4 MW service
- These issues will be resolved in time, with improved energy density batteries, urban planning, and electric grid upgrades - - but in the meantime....?

# The near term transition: **Low emission** Hybrids with significant engine-off, EV operation capability

## A practical, low-risk solution:

- Provides engine-off, EV driving in select areas
- 1-4 EV miles/trip, up to 35% EV miles/day
- Proven propulsion & power system solution
  - Same components as on HEVs
- No infrastructure required
- No “range anxiety”
- No impact to 24 hour/350 mile operations
- Flexible redeployment onto other routes





## Example of electric-range operation - London

**Start:** Aldwych/Somerset House

**Via:** Charing Cross, Westminster,  
Clapham Junction,

**Ends:** Wandsworth Plain

**Length:** 6.26 miles (one way)

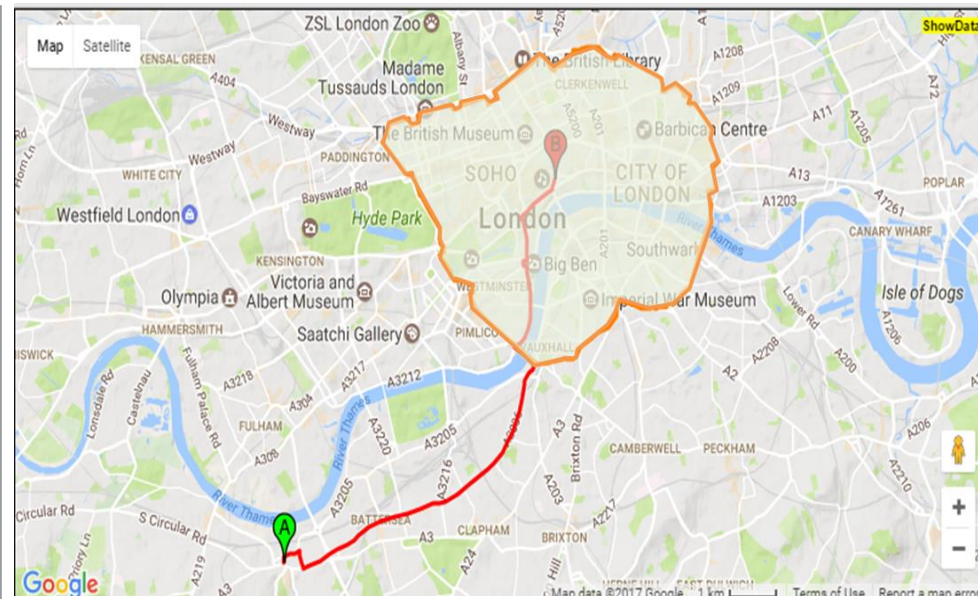
**Journey time:** 28-56 minutes

**Operates:** 05:00 to 00:15

**Max grade:** 4%

**Routes per 24h:** ~22 per bus

- Route starts at Somerset House (within the ULEZ), exiting at Vauxhall Bridge
- Portion of route within the ULEZ: 2.2 miles (one-way) / 4.4 miles (round trip)
- **Can perform 100% engine-off driving within the ULEZ**



# A practical and incremental path to zero

Low

Lower

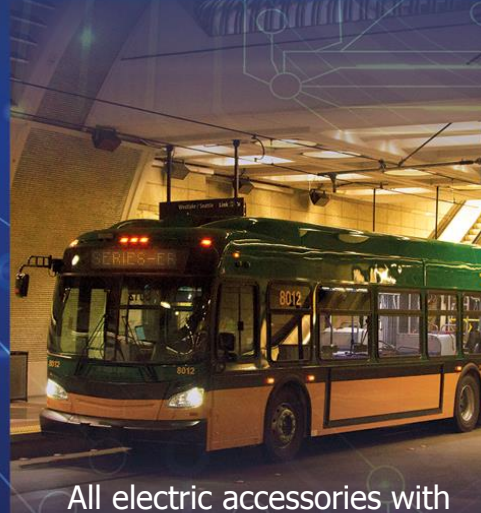
No

## Series-E Hybrid Electric



All electric accessories with stop/start technology

## Series-ER Electric-Range Hybrid



All electric accessories with stop/start, depot driving, and extended-range EV drive

## Series-EV Fully Electric



All electric/zero-emission driving

Increasing battery energy density and charging system maturity

## Summary/discussion

- Zero-emission buses projected to grow significantly in next 10 years
- Challenges remain with range/endurance and/or charging infrastructure/logistics/grid infrastructure
- Extended EV-range hybrids offer a bridge to zero-emission buses and afford the time for the above challenges to sort-out





# Thank you

Please contact us if you have questions

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## Why is the transition period likely?

- Range (size/weight/capacity of battery) & anxiety
  - **Traction Only** Net Energy:
    - Manhattan / OCTA 1.4-1.6 kWh/mi, 6.7/12.5 mph Avg speed
    - Mixed Suburban 1.7-1.9 kWh/mi, 13-20mph Avg Speed
    - Highway 2.0-2.5 kWh/mi, 20-50 mph Avg Speed
  - **Accessory Energy** Contribution (kWh/mi) will depend on duty cycle speed:
    - 2 kW (test\*) .3/.16 (M/O); .15-.1 (MS); .1-.04 (Hwy)
    - 4 kW (min Service) .6/.32 (M/O); .3-.2 (MS); .2-.08 (Hwy)
    - 10 kW (mild day) 1.5/.8 (M/O); .77-.5 (MS); .5-.2 (Hwy)
    - 17+ kW (hot day) 2.5/1.36 (M/O); 1.3-.85 (MS); .85-.34 (Hwy)
      - \* Minimum load to support basic vehicle function, typical for FE test
  - **Total Revenue Service Energy**: 1.9-2.9 kWh/mile depending on mix of above
  - **Therefore: Installed Battery Capacity for 150 mile range:**
    - 445-680 kWh (80% usable, 80% EOL capacity fade)
    - 356-544 kWh BOL (80% usable, EOL range decrease to 120 mi)