

BAE Systems' Power and Propulsion Solutions **Electrifying Transit**

Overview for Granite State Clean Cities Coalition (GSCCC)

December 2017

We help cities **electrify** transit

- World's leading **manufacturer** of series electric propulsion systems
- **Made in USA**
- More than **8,000 hybrid buses** in service today on three continents
- More than 2 billion revenue miles
- Prevented **2 million tons of CO₂ emissions**
- Demonstrating **20 electric buses today**
- Developing innovative **marine vessel & truck electrification solutions**



IVECO

GILLIG

NEW FLYER

SOLARIS

NOVABUS
Driven by your city

ALEXANDER DENNIS

DAIMLER

ElDorado National

Our fleets: global partners



- Series-E electric accessories & anti-idling modes
- HybridDrive Propulsion Systems



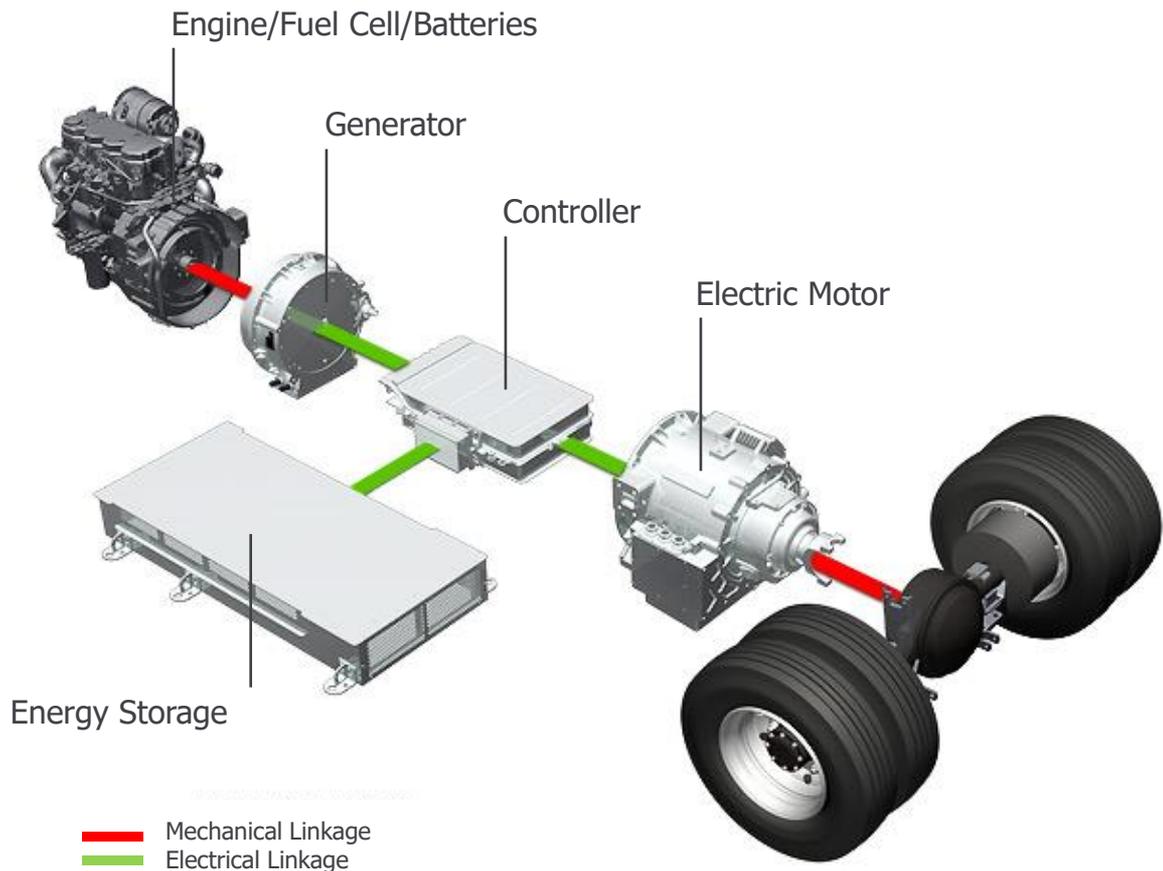
Series hybrid: full electric **propulsion**

No **mechanical link**
between the diesel engine
and the axle

All power comes from the
electric motor

Power flows in **SERIES**
from engine to generator
to traction motor

Adaptable in the future to
ALL ELECTRIC



Series hybrid: **components**

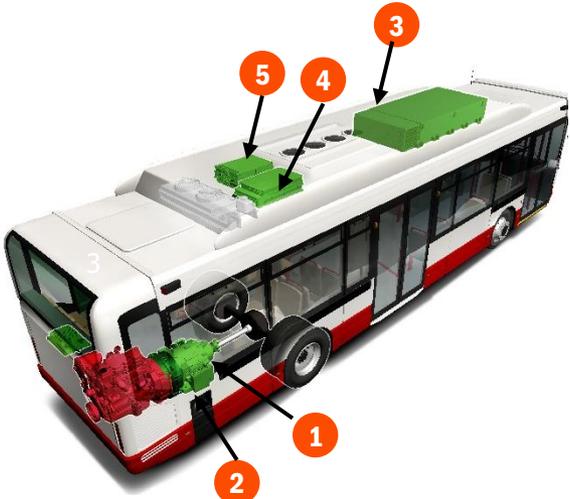
Motor

1



Generator

2



3

Energy Storage System



4

Propulsion Control System



5

Accessory Power System
(Options Available)



Series hybrid: **energy storage options**

ESS-3G-1K



- Ultra-capacitor technology
- **Minimum 12-year life**
- Lightweight
- High efficiency & reliability
- Supports engine anti-idle
- Up to 15% engine-off time

ESS-3G-32K



- Lithium-ion technology
- Larger energy capacity
- 8-year life* & high reliability
- Environmentally-sealed
- Supports zero-emission driving
- **Up to 35% EV drive miles***

* EV duty cycle dependent

Series hybrid: **electric operating modes and ESS compatibility**



Stop/Start

- Reduces idling at bus stops for quieter boarding
- Can be supported with **3G-1K Ultra cap** or **3G-32K Lithium Ion ESS**



Depot Drive

- Shuts engine off in depots for improved air quality and noise
- Requires **3G-32K Lithium Ion ESS**



Electric Range

- Allows zero-emission operation near hospitals, campuses, historic districts, tunnels, etc.
- Requires **3G-32K Lithium Ion ESS**

One system, **three solutions**

Series-E Hybrid Electric



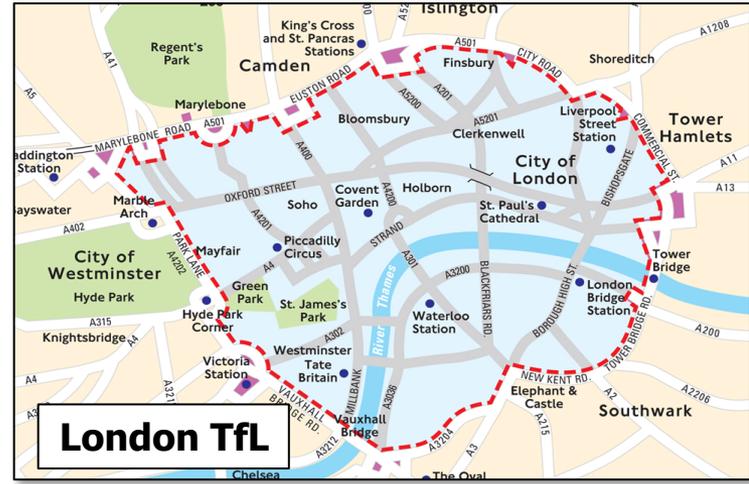
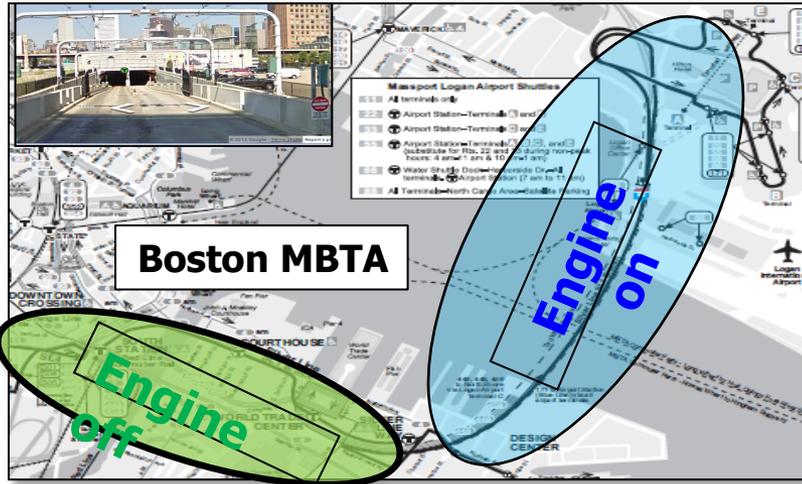
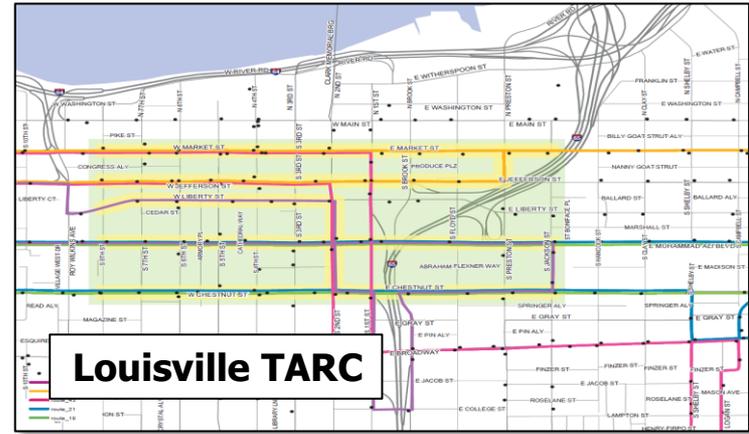
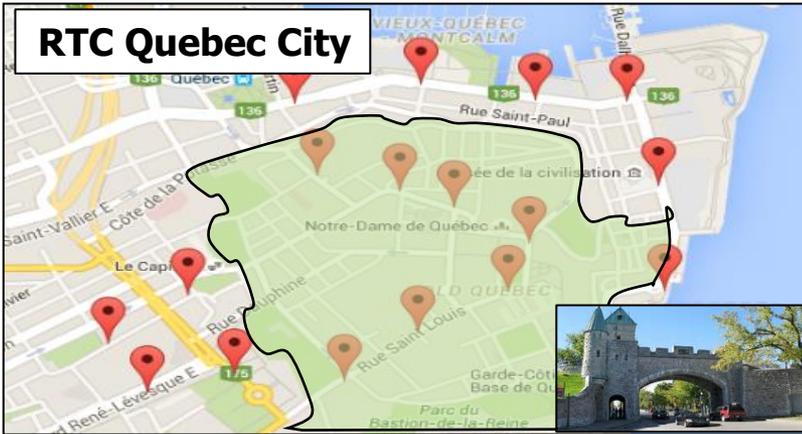
Series-ER Electric-Range Hybrid



Series-EV Fully Electric



Series-ER (Electric Range) New Products and Capabilities

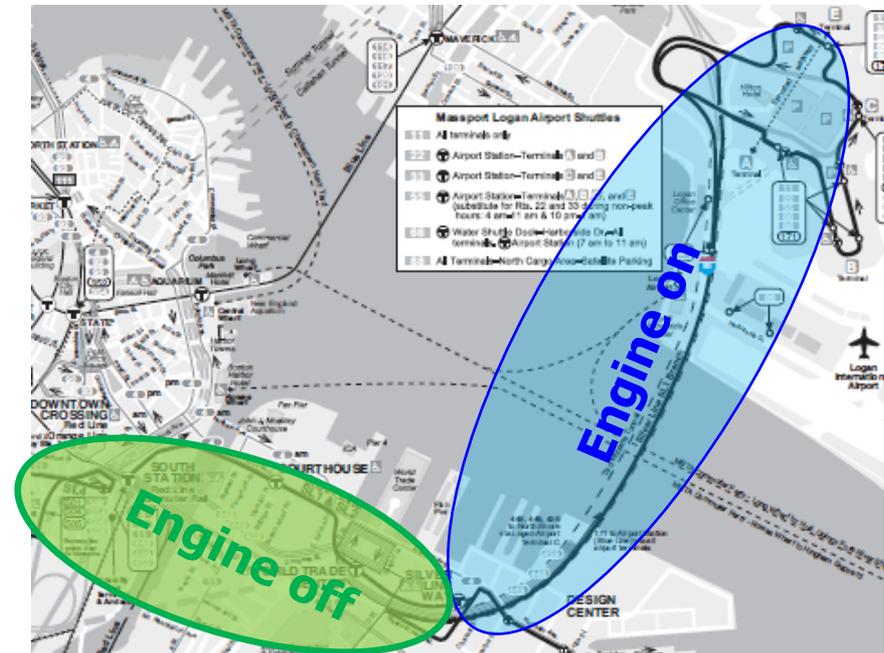


Series-ER (Electric Range) zero emission travel inside Boston tunnel

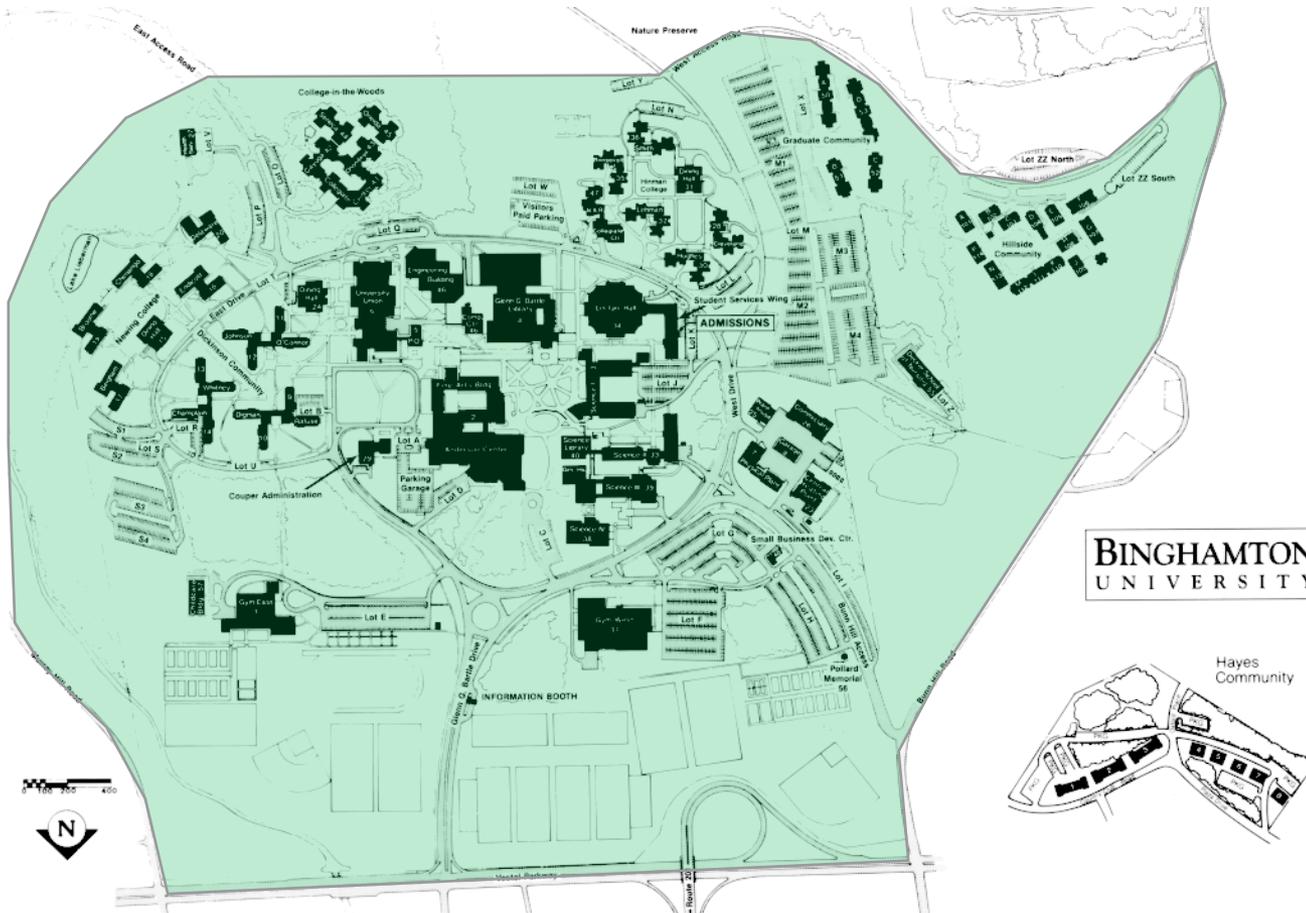


Key information

- ✓ **EV length** 2.2 miles (3.5 km)
- ✓ **EV/HEV** 48 %/ 52%
- ✓ **Max grade** 5%
- ✓ **Operating** 12 hours
- ✓ **Daily EV** 53 mi (85 km)
- ✓ **Daily Distance** 110 mi (176 km)



Series-ER (Electric Range) New Products and Capabilities

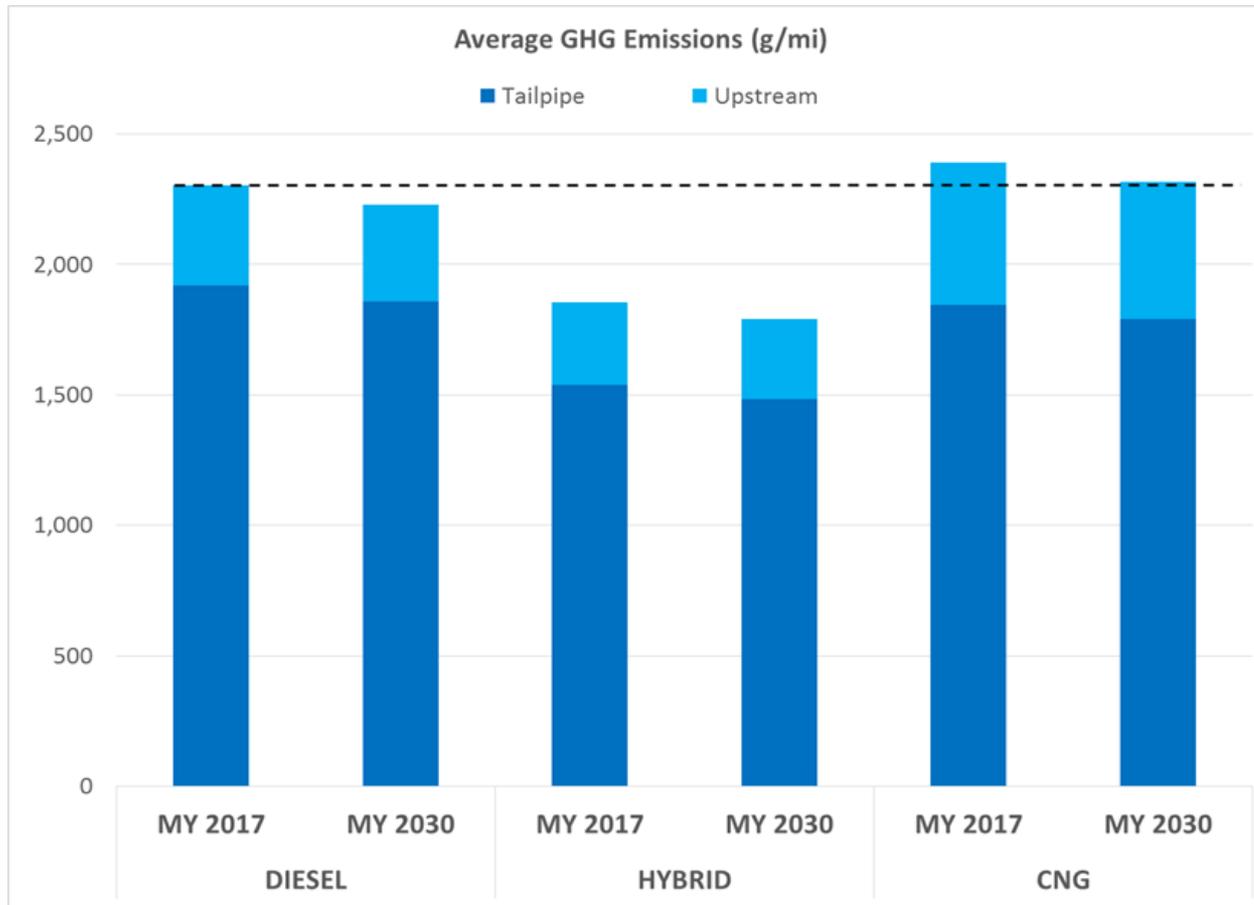


The 1st Grid-Free, Zero Emission University Bus Service in U.S.

- 2017 LowNo Proposal
- BC Transit bus service at BU
- Geo-fenced campus to trigger engine off operation
- No charging infrastructure
- No driver intervention

Diesel vs. Hybrid vs. CNG transit buses

Projected **GHG Emissions**

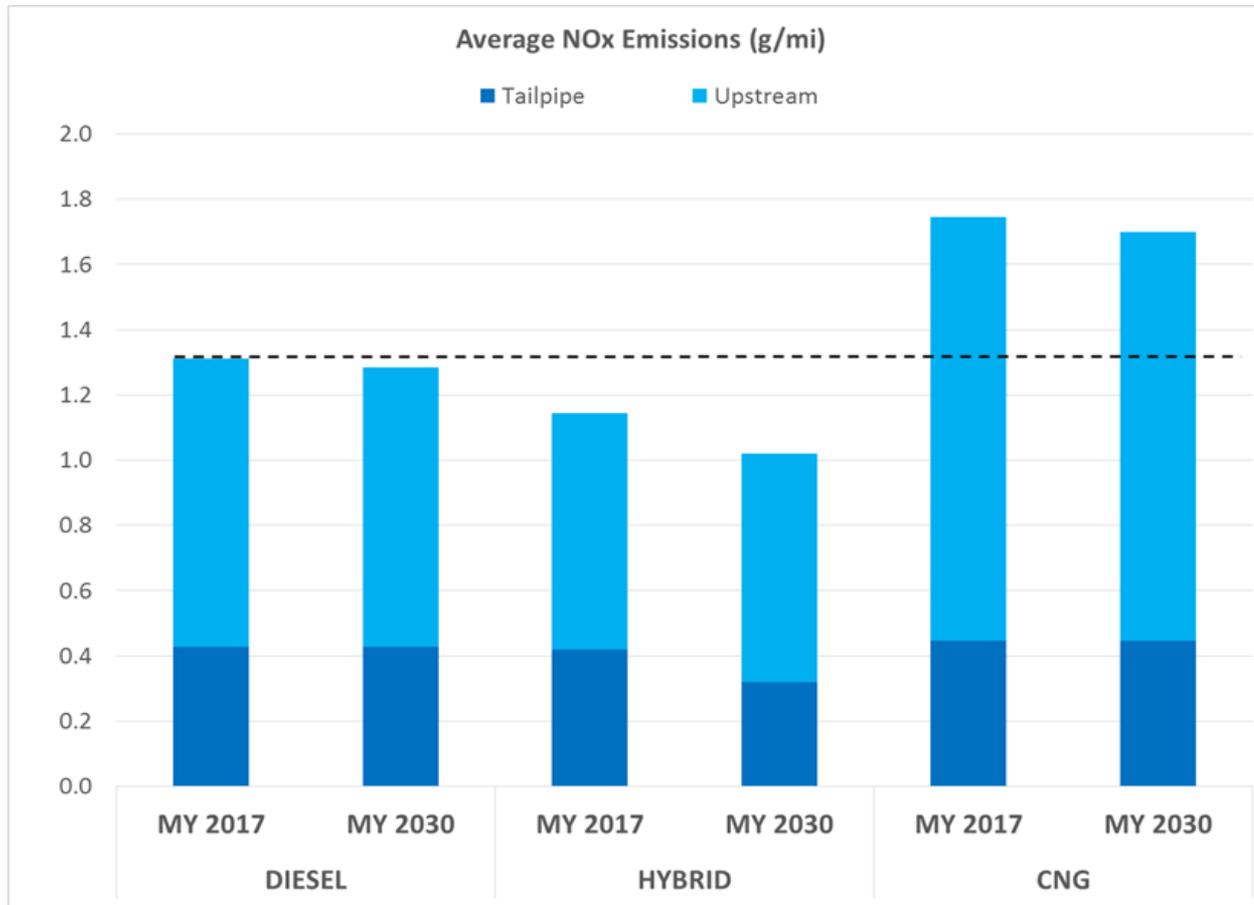


- In Dec 2015, Milwaukee County DoT (MCDOT) commissioned a 3rd party consultant (MJ Bradley) to analyze alt fuels for a full fleet conversion at Milwaukee County Transit System (MCTS)
- On Nov 30, 2016, the MCDOT reported its results to their Board

Source: [Milwaukee County Transportation, Public Works and Transit Committee Board meeting, 11/30/2016](#)

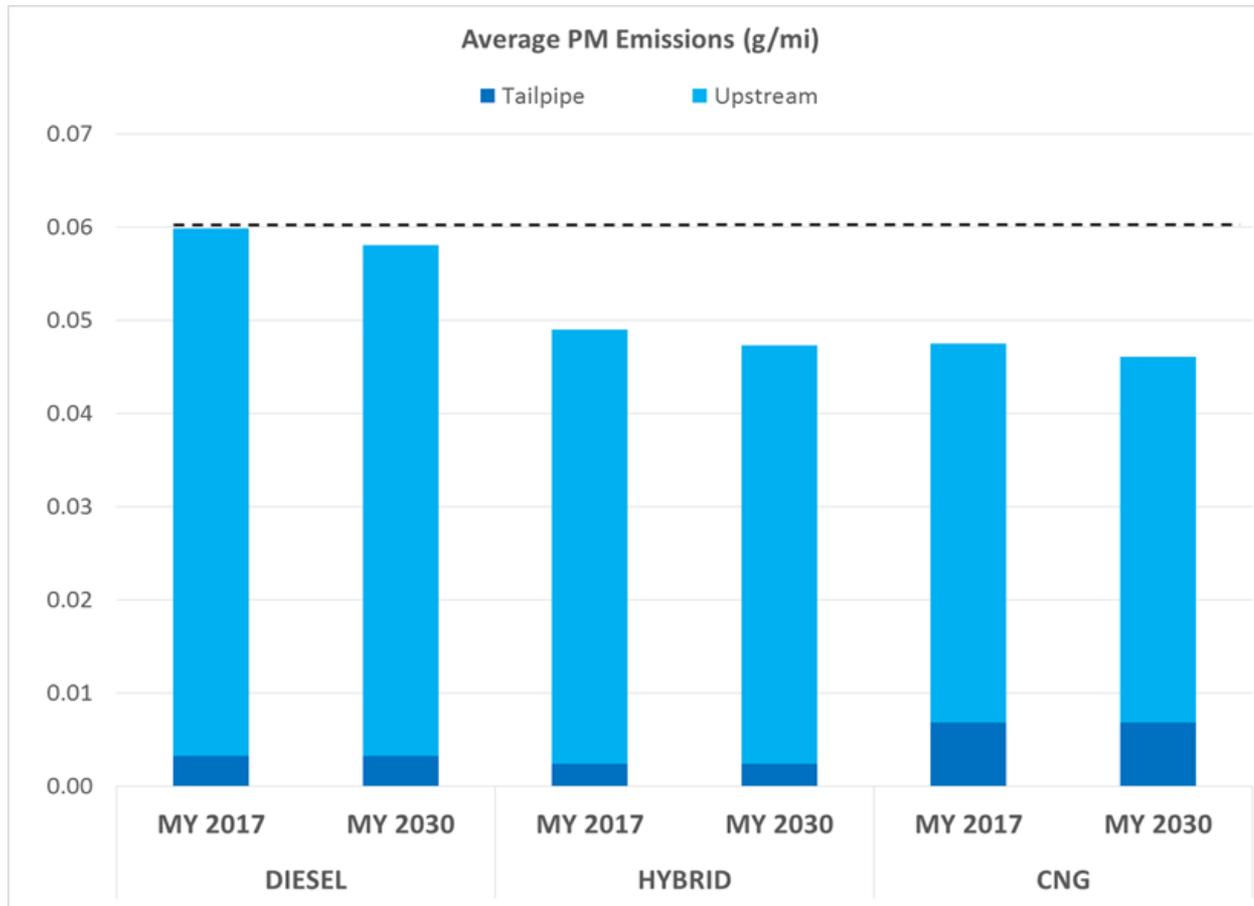
Diesel vs. Hybrid vs. CNG transit buses

Projected **NOx Emissions**



- Hybrids' fuel savings and independence from creating additional upstream emissions lead to significant NOx emissions reductions
- CNG burns more fuel per mile along with higher upstream & tailpipe CH₄ emissions = higher NOx

Diesel vs. Hybrid vs. CNG transit buses Projected **PM Emissions**



- Hybrids' fuel consumption reduction and CNG's lower carbon content both provide significant PM advantages over Diesel buses

Increasing Efficiency Improvements

More Electrification: New products, projects and platforms

HybriGen®
Hybrid-Electric
Power &
Propulsion



Hybrid Assist
for engine
peak & low idle



HybriGen® Zero
as auxiliary
power genset



Class 8
CNG Hybrid-
Electric
Tractor



Class 8
Hydrogen
Fuel Cell
Tractor



Class 8
Hybrid-Electric
Refuse Truck

Why BAE Systems?

We continue to invest and innovate

BAE Innovations

- 1st **LiIon** Battery
- 1st **Accessory electrification**
- 1st Engine **Stop/Start**
- 1st **Electric range** hybrid
- Delivering **zero emission** solutions today



■ **Industry leader** in transit electrification

BAE SYSTEMS
INSPIRED WORK

Congratulations
Power & Propulsion Solutions
for your innovative
technology

The Canadian Urban
Transit Association (CUTA)
presents BAE Systems with the
CUTA Leadership Award for
Transit Electrification. Read more.



CS-17-F69

Thank you

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