EVS35
OSL2022

Fuel-Fired Heaters in ZE Transit Buses

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CALSTART
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Over 300 Members

WHAT IS A FUEL-FIRED HEATER?

- CARB definition: “a fuel burning device that creates heat for the purpose of warming the passenger compartment of a vehicle but does not contribute to the propulsion of the vehicle.”
- BEBs – off-board heating demand
- FFH (red) & Fuel tank 11gal/42L (yellow)
- Transit buses with FFH are not considered zero-emission in California
  - Cannot receive incentive funding
  - New York incentive program allows buses with FFH

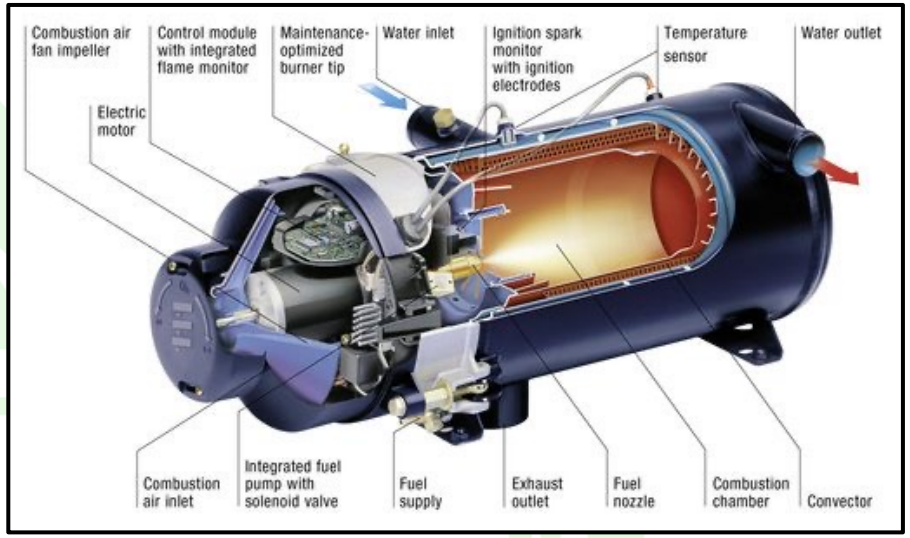
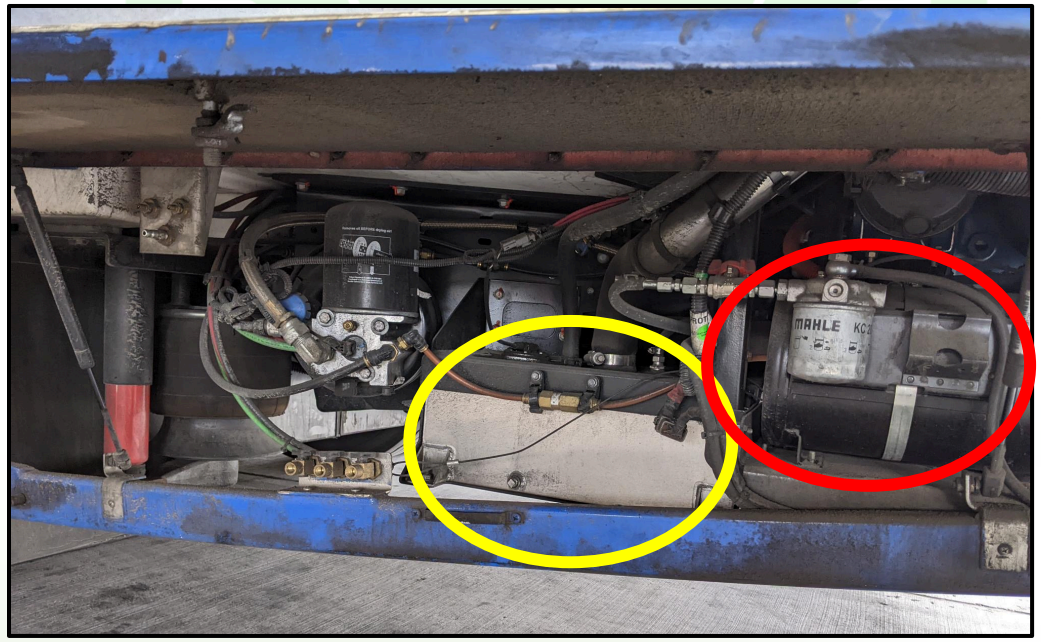


Image Credit: Eberspaecher



FFH MANUFACTURERS

FFH Heater Manufacturer	Valeo	Proheat	Eberspaecher
Bus OEM(s)	BYD, New Flyer, Nova Bus	New Flyer	Proterra
Model(s)	Spheros Thermo (230/300/350)	Proheat: X30	Hydronic L30
Example of Transit Agency Usage	• Link Transit – Washington State • Metro Transit – Minneapolis/St. Paul • Utah Transit Authority (UTA) - Salt Lake City, UT (Electric buses)	• Utah Transit Authority (UTA) - Salt Lake City, UT (Diesel buses)	• Chicago Transit Authority (CTA) – Chicago • Washoe RTC – Reno, NV
Fuel Consumption	• Thermo 230: .79 g/h • Thermo 300: 1.05 g/h • Thermo 350: 1.18 g/h	0.1 – 0.31 gal/hr	0.96 gal/hr
Heat Output	• Thermo 230: 23 kW • Thermo 300: 30 kW • Thermo 350: 35 kW	2.9 – 9.1 kW	30 kW

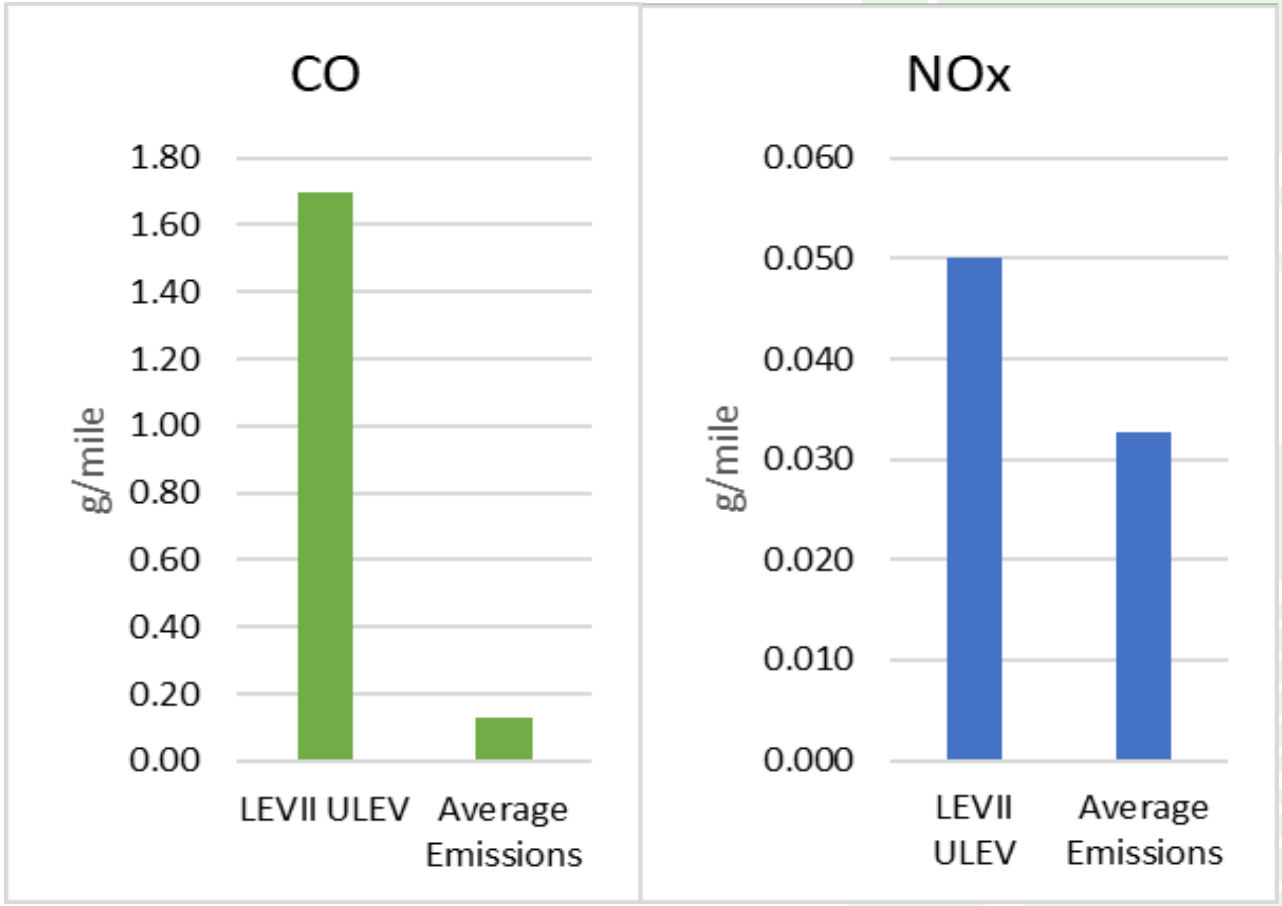
CA AIR RESOURCES BOARD EMISSION STANDARDS

- Current Emission requirements on FFHs for heavy-duty diesel engine vehicles school buses and Class 8 sleeper trucks follow LDV vehicle standards:
- ULEV
  - NMOG (g/mi) – 0.040
  - CO (g/mi) – 1.7
  - NOx (g/mi) – 0.05
  - Formaldehyde (mg/mi) – 8

LEV II Exhaust Mass Emission Standards for New 2004 through 2019 Model LEVs, ULEVs, and SULEVs in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes

Vehicle Type	*Durability Vehicle Basis (mi)*	*Vehicle Emission Category*	*NMOG (g/mi)*	*Carbon Monoxide (g/mi)*	*Oxides of Nitrogen (g/mi)*	*Formaldehyde (mg/mi)*	*Particulates (g/mi)*
All PCs; LDTs 8500 lbs. GVWR or less	50,000	LEV	0.075	3.4	0.05	15	n/a
		LEV, Option 1	0.075	3.4	0.07	15	n/a
Vehicles in this category are tested at their loaded		ULEV	0.040	1.7	0.05	8	n/a

CARB EMISSION COMPARISON



(g/mi)	NOx	CO	Formaldehyde	NMOG
LEV II ULEV	0.050	1.70	0.0080	0.0400

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UN ECE) – R122

- Regulation No 122 (Uniform technical prescriptions concerning the approval of vehicles of categories M, N and O with regard to their heating systems)

TEST PROCEDURE FOR EXHAUST EMISSION OF COMBUSTION HEATERS

1. Operate heater for one hour at maximum output in conditions of still air (wind speed ≤ 2 m/s) and an ambient temperature of 20 ± 10 °C. If, however, having selected the maximum output the heater switches off automatically in less than an hour, the measurements may be made before switch-off.

2. The dry and undiluted exhaust emissions, measured using an appropriate meter, shall not exceed the values indicated in the following table:

Parameter	Heaters using gaseous fuels	Heaters using liquid fuel
CO	0,1 % vol.	0,1 % vol.
NO_x	200 ppm	200 ppm
HC	100 ppm	100 ppm
Bacharach reference unit (1)	1	4

(1) Reference unit 'Bacharach' ASTM D 2156 is used.

3. The test shall be repeated in conditions equivalent to a vehicle speed of 100 km/h (or maximum design speed of the vehicle in cases where the maximum speed is less than 100 km/h). Under these conditions the CO value must not exceed 0,2 % vol. If the test has been carried out on the heater as a component, then it need not be repeated in the case of the vehicle type in which the heater is installed.

EMISSIONS TESTING COMPARISON

CARB

- Maximum heating capacity with a cold start for 20 minutes
- Ambient temp: 68F - 86F (20C – 30C)
- Divide the grams of emissions by 20 → multiplied by 3.0 minutes per mile for a grams per mile value
- Units: grams/mile

UN ECE R122

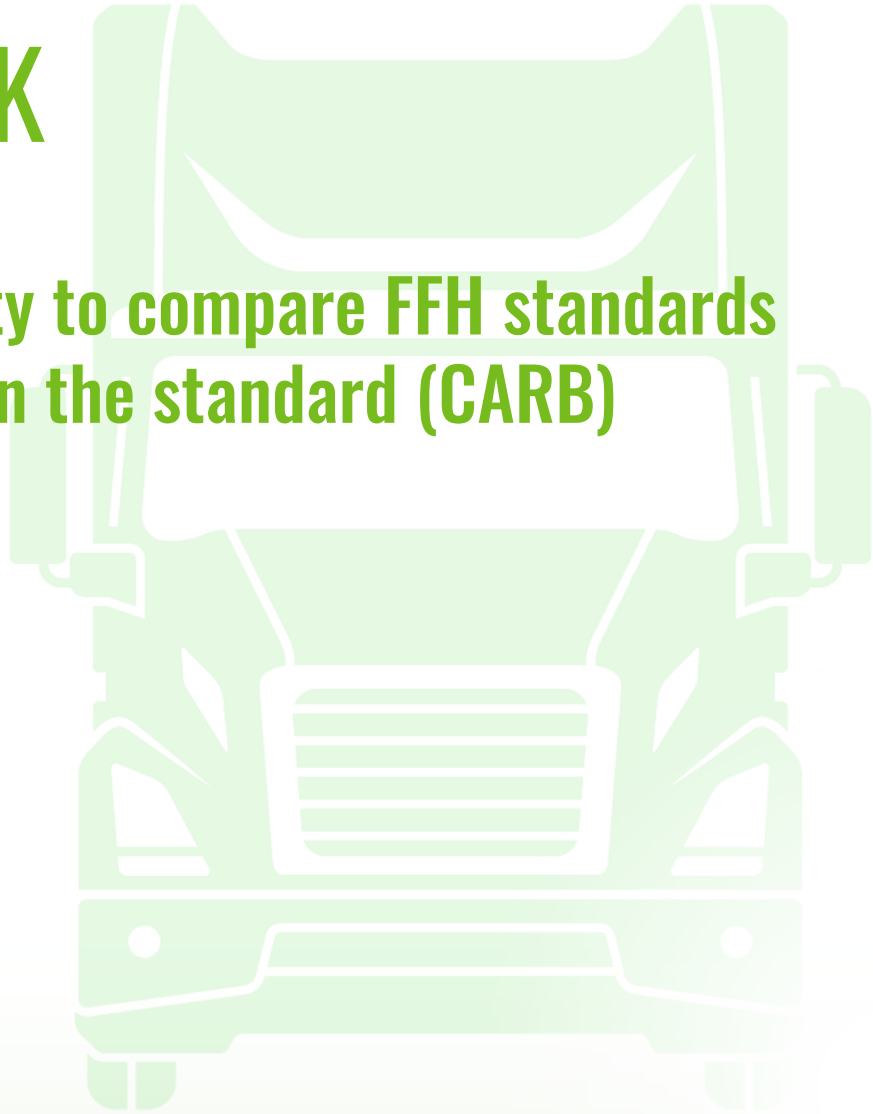
- Maximum heating output in conditions for 1 hour with still air (wind speed ≤ 2 m/s)
- Ambient temperature of 20 ± 10C. (58F – 78F)
- Measure the dry and undiluted exhaust emissions
- Units: ppm & bacharach (optic)

TRANSIT AGENCY EXAMPLES

- Heating BEBs in below freezing: +2.09-3.22 kWh/mi (1.30-2.00 kWh/km)
- FFH: primary or secondary heating source
- Midwest transit agency (60ft-articulated)
  - 30 gal (114 L) diesel/bus/month for heating
  - On avg, the buses would need additional ~1800 kWh/month for heating
  - E-heater: +0.71 kWh/mi (0.44 kWh/km)
- Mountainous Transit Agency (40ft)
  - W/ FFH: heating energy: +0.08 kWh/mi (0.05 kWh/km)
  - W/O FFH: heating energy: +0.55 kWh/mi (0.34 kWh/km)

CONCLUSION/FUTURE WORK

- CARB, EU unit mismatch created difficulty to compare FFH standards
- FFH emissions are significantly lower than the standard (CARB)
- Battery predictions
  - Cost
  - Gravimetric (wh/kg)
  - Volumetric (wh/l)
- ZE bus thermal management
  - Increased insulation
  - Driver climate zones
- Demonstration
  - Ethanol catalytic heater



THANK YOU!

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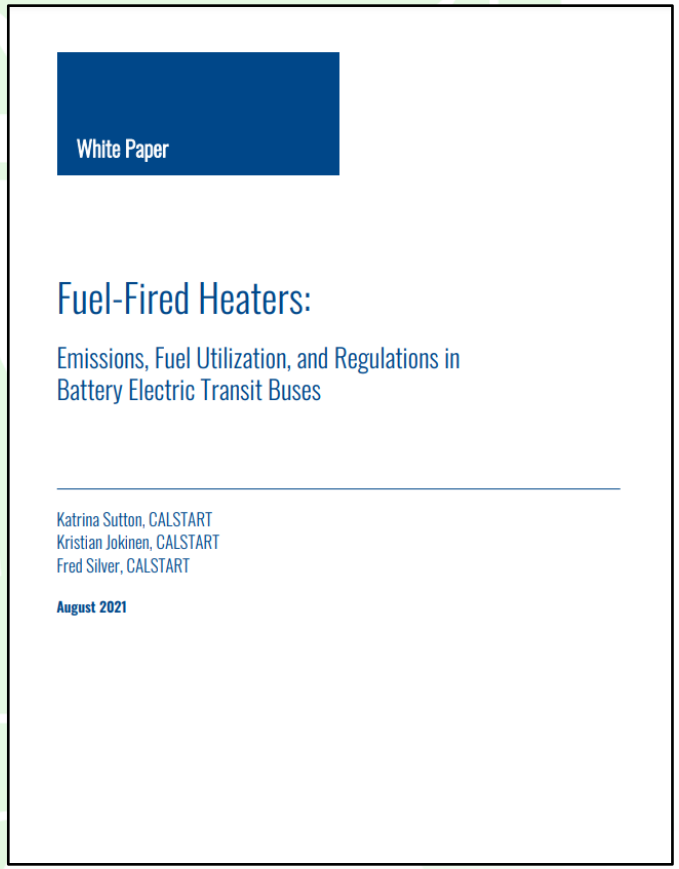
- **Funding – Federal Transit Administration (US FTA)**


White Paper

Fuel-Fired Heaters:

Emissions, Fuel Utilization, and Regulations in Battery Electric Transit Buses

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