Fuel-fired heaters: an invisible source on battery electric buses

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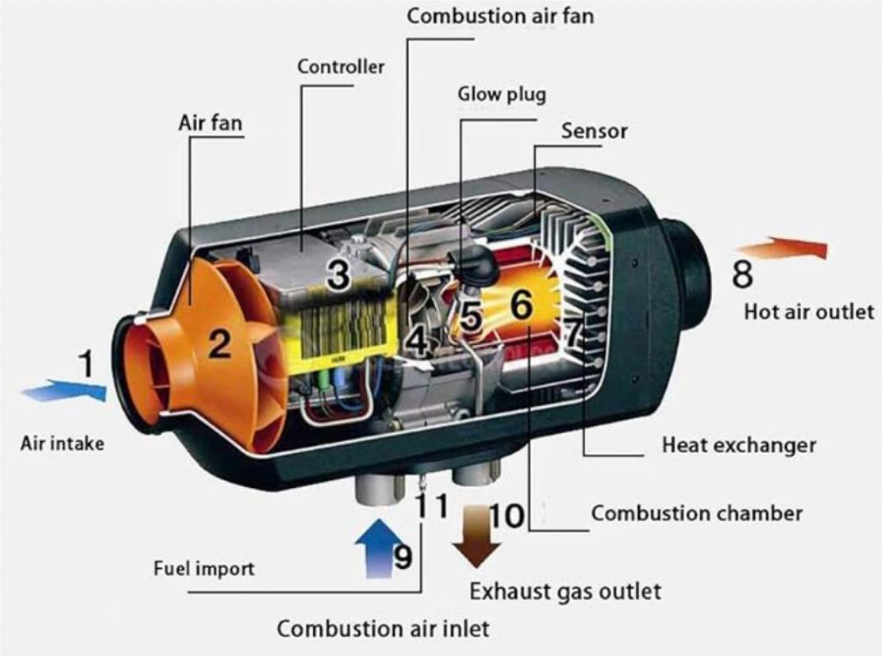
What is a fuel-fired heater (FFH)?

Figure 1
Inner structure of fuel-fired heater



Source: Chong (2019). Reprinted with permission.

- Heating device, commonly used in EV
- A mini “boiler” burning fuels in a combustion chamber
- Simple structure and straightforward control logics: on/off control determined by cabin temperature.
- No aftertreatment of exhaust gases

Regulatory landscape: How are FFHs regulated in different regions?

Table 1

Regulatory scope and limits in three regional standards for fuel-fired heaters

	China JB/T 8127-2011 (regulated by average value)	California LEV II ULEV	EU R122 (regulated by peak value)
NO_x	< 100 ppm	< 0.05 g/mi	< 200 ppm
CO	< 300 ppm	< 1.7 g/mi	< 1,000 ppm
HC	< 5 ppm		< 100 ppm
Formaldehyde		< 0.008 g/mi	
NMOG		< 0.04 g/mi	
PM			< 4 smoke number (Bacharach conversion method)

- Outdated regulations, established more than a decade ago.
- Emissions control system are not required
- Particulate matter and GHG (CO_2, CH_4) are not regulated
- Incomparable across regions due to different metrics

FFHs are a challenge to current emission regulatory frameworks

- Emissions not from vehicle tailpipe: Not covered by pollutant emission standards
- Usually retrofitted to vehicles after being sold in second stage manufacturing
- An increasing challenge for zero-emission vehicles. Trade-off between cabin thermal management and electric range.

To understand the issue better, ICCT tested an electric coach equipped with an FFH

The tested bus model

The FFH is placed here!

Specifications of the bus model

Brand	King Long
Model	XMQ6112AYBEVL05
Gross vehicle weight	18,000 kg
Passenger capacity	52
Max output	360 kW
Battery capacity	338 kWh

Here's how the FFH analyzed looks in detail

The tested FFH on the bus

Specifications of the FFH

Manufacturer	Hebei Hongye Yongsheng Automotive Heater Co. Ltd.
Age	Within 6 months of manufacture
Heating method	Liquid
Fuel type	Diesel
Output power	165 W
Heating power	35 kW
Input type	Battery
Rated voltage	24 V
Temperature control method	Heater shuts downs when water is heated to 85 °C; the heater reignites to reheat when temperature drops to 65 °C
Heating areas	Heating by compartment and front windshield defrosting
Fuel consumption	3.6 kg/h or 4.24 L/h
Flow rate of pump	5,000 L/h
Weight	28 kg
Installation	At factory

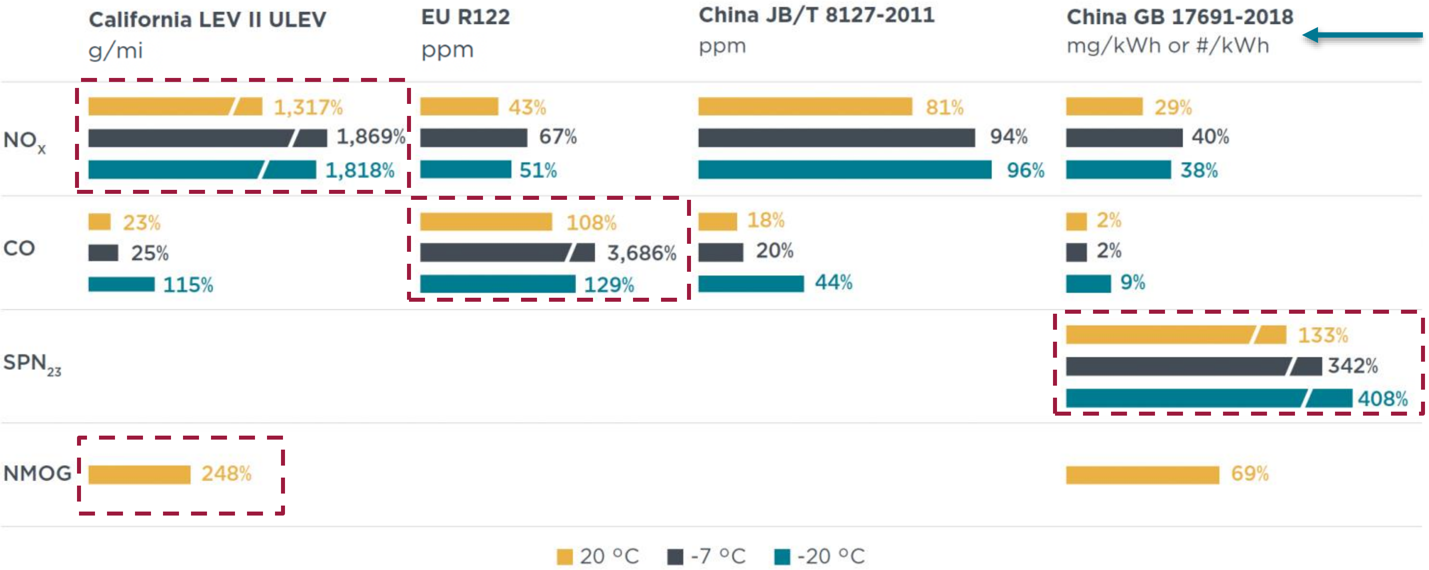
Test schedule – tested in 20℃/-7 ℃/-20℃.

Temperature	Vehicle state	Mode of heater	Test cycle	Number of tests	Tested pollutants
20 °C	Idle	Defrost and defog activated, maximum airflow	Stationary test (until the heater shuts off automatically when the coolant reaches 85 °C)	2	Pollutants: NO_X, CO, THC, SPN_{10}/SPN_{23} Greenhouse gases: CO_2, CH_4, N_2O,
	Running	Defrost and defog activated, maximum airflow	Driving test (cycle: CHTC-B)	3	
		Defrost and defog activated, minimum airflow	Driving test (cycle: CHTC-B)	1	
-7 °C	Idle	Defrost and defog activated, maximum airflow	Stationary test (until the heater shuts off automatically when the coolant reaches 85 °C)	3	
-20 °C	Idle	Defrost and defog activated, maximum airflow	Stationary test (heater works for at least 1 hour if coolant fails to reach 85 °C)	3	

Key findings – emissions exceed limits in different regions

Figure 5

Emissions test results at 20 °C, -7 °C, and -20 °C and percentage to regulatory limit in various regional standards



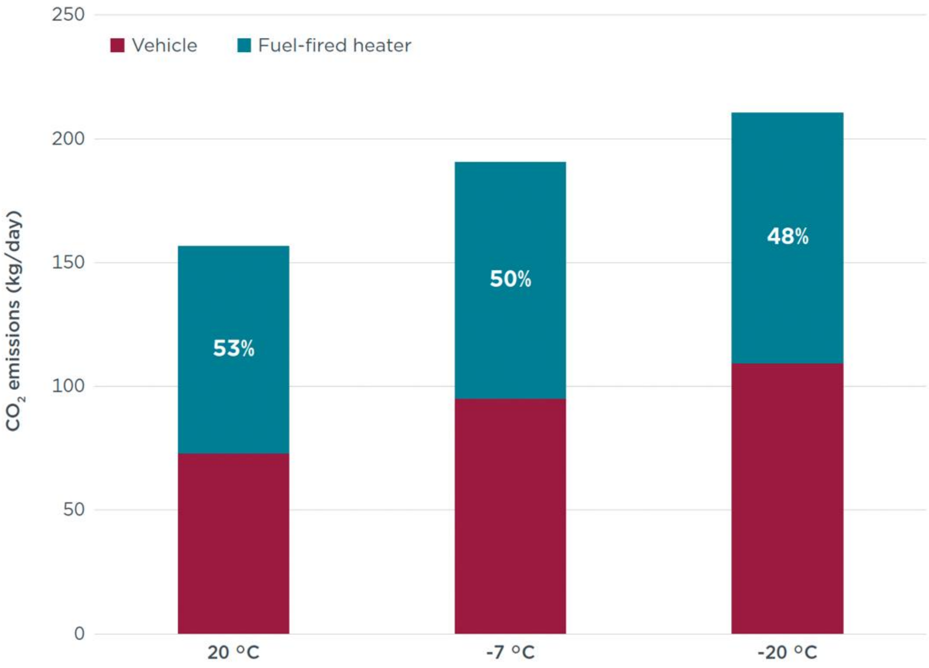
This is the China VI pollutant emissions std for diesel heavy duty vehicles

Note: The EU R122 and China VI standard (GB 17691-2018) regulate by the peak value of the test, and the other regulations are applied to the average value.

Simulated total CO_2 emissions by temperature from FFH

Figure 6

Total CO_2 emissions from the coach and fuel-fired heater at 20 °C, -7 °C and -20 °C



- CO_2 emissions from FFH accounted for about **50%** of total CO_2 emissions associated with the electric coach while in use (assumption: 180km/day, 620.5g CO_2/kWh).
- CO_2 emission by the electric bus per day, if FFH involved in: 190kg at -7℃; 210kg at -20 ℃
- What to expect: FFH share may increase due to lower carbon intensity of power grid, so lower emission from electric buses.

Conclusion and recommendations

Key takeaways:

- **Inadequate regulation:** Current global standards for FFHs lack limits for critical pollutants like particulate matter (PM) and greenhouse gases (CO_2, CH_4).
- **Severe pollution:** this study found substantial emissions of particulate matter and NMOG, and PN exceeded the regulatory limits of tailpipe regulations for diesel vehicles.
- **High climate impact:** The tested FFH accounted for about 50% of total CO_2 emissions associated with the electric bus while in use, and the share would be even higher with a cleaner power grid.

Recommendations:

- **Expand standards:** An update of FFH emission regulations is warranted to include limits on PM, NMOG, and greenhouse gases.
- **Integrate into vehicle type-approval procedure**: Emissions from FFHs are non-negligible. Regulators could consider incorporating them in future certification procedures.
- **Dive deeper with more tests**: Currently studies about FFHs emission performance are still scarce, more studies and tests are needed to update emissions inventories and design the right policies.


WORKING PAPER

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Emissions from a fuel-fired heater on a battery electric coach: Tests in China

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BACKGROUND

Around the world, electric buses are becoming common in bus fleets due to their efficiency and environmental benefits. In cold regions, electric bus operations are more demanding. Low temperatures reduce battery performance because both battery heating and cabin heating consume a large amount of electricity; this affects driving range and operational efficiency. According to prior analysis by the ICCT, cabin heating at temperatures as low as -20 °C can consume up to 50% of a vehicle's total energy (Mao et al., 2023b).

In northern regions of China, where winter temperatures can reach -20 °C, electric bus operators and fleet managers typically install auxiliary heating devices known as fuel-fired heaters (FFHs) to maximize the driving range of buses and coaches. As independent heating systems, FFHs provide heat to the passenger cabin without drawing on battery power (Figure 1). By burning diesel or gasoline to generate heat, FFHs optimize the efficiency of winter operations and improve the overall durability of the vehicle. At the same time, FFHs are a source of emissions, and many FFHs lack aftertreatment systems such as diesel particulate filters.

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For more information, please refer to the publication from our website ***theicct.org***!

https://theicct.org/publication/emissions-from-a-fuel-fired-heater-on-a-battery-electric-coach-tests-in-china-may25/

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