We thank both reviewers for the careful reading and valuable comments. Below we provide our point-by-point responses to the reviewers' comments. In the following context, raised comments/suggestions are marked in **black**, responses are presented in **green**, and changes to the manuscript/supplement information are indicated in **blue**.

In addition to suggestions by the reviewers, we have made some minor technical changes to the manuscript, e.g. removed reference to In Prep. Manuscript by Ala-Hakuni et al. and fixed some typos.

Reply to Anonymous referee #2

The manuscript by Oikarinen et al. reports experimental data for emission of both gas and particulate matter species from fuel-operated auxiliary heaters. The experiments include operation of the heater under a winter-time condition, making the study to be relevant to understand the real environment. Overall, the experiments seem to be well-conducted, and the data are well organized. The dataset would be useful for understanding the urban environment. Though the manuscript is a good report of data, all the employed measurement methods are well-established ones (i.e., contribution to the advancement to atmospheric measurement technique is unclear). The reviewer is not sure if the manuscript fits well with the scope of the journal. The reviewer leaves this concern to the editor. Regarding the main content of the manuscript, I only have a few minor comments.

We thank the referee for positive remarks about our manuscript. Regarding the subject matter of this manuscript being outside the scope of AMT journal. We believe that the presented dataset, although based mainly on established methods, contributes to the atmospheric measurement community by providing novel and comprehensive real-world data on a rarely studied but relevant emission source. However, we fully respect the editorial decision regarding suitability for AMT.

Line317

The authors report emission of HCl. Is Cl included in fuel, or other material of the heater?

We expect that the Cl is present in the fuel rather than material of the heater. Despite that as chemical composition of the fuel was not analysed separately in this study, we cannot say that with certainty. Possible sources for trace amounts of chlorine present in the fuels might be impurities leftover from crude oil used to refine fuels or due to contamination of the fuels with chlorine-based cleaning agents used to clean fuel tanks of gas stations or tanks used to transport the fuel from refinery to gas station as reported by Battaglia et al., 2025. HCl was measured due to its corrosive potential as gaseous hydrogen chlorine can form strong hydrochloric acid when it interacts with water. Brief description of HCl emission has been added to section 3.1.2 to address the presence HCl emission in more detail.

HCl concentrations of 0.27 ppm and 0.26 ppm were measured for gasoline and diesel AHs respectively with corresponding EF_{fuel}s of 6.6 mg kg_{fuel}^{-1} and 8.9 mg kg_{fuel}^{-1}. HCl was mostly released evenly during whole heating cycle with only spikes detected for gasoline AH during shutdown. Possible sources of HCl emissions from AHs could be trace amounts of chlorine in fuel leftover from crude oil used to refine fuels or due to contamination of the fuel with chlorine-based cleaning agents used to clean fuel tanks of gas stations or tanks used to transport the fuel from refinery to gas station (Battaglia et al., 2025).

Line336

Emission of SO2 is reported. Could the authors clarify the sulfur contents of the fuels that were employed for the experiment? It could influence the emission factor of SO_2.

Specific sulfur contents of the measured fuels were not verified independently based on chemical analysis of the fuel, but European Union has regulation limiting the maximum sulfur content of the fuel to 10 mg/kg_{fuel}. Measured SO_2 EFs are assumed to correspond to mass fraction of sulfur content in the fuels used in AH experiments. Ratio of molar masses of SO_2 to sulfur (64.066 g/mol for SO2, and 32.06 for Sulfur, so ratio is ~2) can be used to convert SO_2 EF_{fuel}s of exhaust to estimates for sulfur content of the fuel assuming that detected SO_2 originates solely from combustion of fuel.

Converting EF_{fuel}s to estimates of fuel sulfuric content of gasoline 2.6 mg/kg_{fuel} would be well below regulation limit of maximum allowed sulfur content of 10 mg/kg_{fuel}, but diesel would be above allowed limit with 29 mg/kg_{fuel}, with regular diesel specifically having 14 mg/kg_{fuel} and renewable diesel having higher estimated content of 44 mg/kg_{fuel}. Even for more conservative estimate where EF_{fuel} of SO_2 is calculated from only from stable operation period emissions the sulfur content of the diesel fuel would still be on average be 24 mg/kg, with regular diesel specifically having 10 mg/kg_{fuel} and renewable diesel having higher estimated content of 37 mg/kg_{fuel}.

Following addition has been made to section 3.1.2 about estimates of fuel sulfur content based on SO_2 measurements.

SO_2 emissions from AHs are not directly regulated, but European Union has regulation limiting the maximum sulfur content of commercial fuels used in road vehicles to 10 mg kg_{fuel}^{-1} (Directive, 1998). Assuming that all detected of SO_2 originates solely from combustion of sulfur present in the fuel EF_{fuel} of SO_2 can be used to estimate sulfur content of the fuel. The fuel sulfur contents corresponding to gasoline and diesel AH measurements would be 2.6 mg kg_{fuel}^{-1} and 29 mg kg_{fuel}^{-1} respectively, which would be well below the regulation limit for gasoline but above the limit for diesel. Of the two types of diesel fuel measured the renewable diesel had higher SO_2 emissions with corresponding estimates for fuel sulfur contents being 44 mg kg_{fuel}^{-1} and 14 mg kg_{fuel}^{-1} for renewable and regular diesel, respectively. Even for more conservative estimate where EF_{fuel} of SO_2 is calculated from only from stable operation period emissions the sulfur content of the diesel fuel would still be on average be 24 mg/kg, with regular diesel specifically having 10 mg kg_{fuel}^{-1} and renewable diesel having higher estimated content of 37 mg kg_{fuel}^{-1}. Fuel sulfur contents higher than 10 mg kg_{fuel}^{-1} allowed by regulation has also been observed for similar renewable diesel as was used in this study based on chemical characterization of the fuel, where fuel sulfur content of 11 mg kg_{fuel}^{-1} reported (Karjalainen et. al., 2019). So similar renewable diesel as was used in this study having higher than regulation limit of sulfur is not unprecedented.

Line380

It is interesting that usage of the renewable diesel influences the emission of OGCs. Could the authors add further descriptions about the cause?

We thank the reviewer for the comment. The fuels used were commercial pump-quality fuels, and similar (diesel) fuel types, though not from the same batches, have been characterized in detail in previous work (Karjalainen et al., Environ. Sci. Technol. 2019).

The observed lower OGC emissions with renewable diesel are likely related to its chemical composition and combustion characteristics. This renewable diesel contains almost no aromatic compounds and consists mainly of paraffinic hydrocarbons, while conventional fossil diesel contains significant amounts of aromatics (∼30% w/w). Aromatic compounds are known to be more resistant to complete combustion, leading to higher emissions of unburned or partially oxidized organic species.

In addition, the higher cetane number and heating value of renewable diesel promotes more efficient combustion, leading to reduced formation of organic gaseous compounds. The improved combustion characteristics of paraffinic renewable diesel fuels have also been observed before. https://pubs.acs.org/doi/full/10.1021/acs.est.9b04073

Following additions have been made to section 3.1.3 regarding possible effects of diesel fuel type to OGC emissions:

The observed lower OGC emissions with renewable diesel are likely related to its chemical composition and combustion characteristics. While chemical composition of used fuels was not independently verified in this study it has been characterized in detail for similar diesel fuel types as were used in these experiments (Karjalainen et al., 2019). Based on that renewable diesel fuel used in these experiments contains almost no aromatic compounds and consists mainly of paraffinic hydrocarbons, while regular fossil diesel contains significant amounts of aromatics (28.6 wt %). Aromatic compounds are known to be more resistant to complete combustion, leading to higher emissions of unburned or partially oxidized organic species. In addition, higher cetane number and heating value of renewable diesel compared to regular diesel enables more efficient combustion, leading to reduced formation of organic gaseous compounds due to incomplete combustion of hydrocarbons present in the fuel.

Line 369

The reported particle number concentration is in the range of 10^7 # cm-3. Could the coincidence issue influence particle counting by the CPC for this high concentration range? If so, how much?

While the reported particle number concentrations were in the range of 10^7 # cm^{-3}, which would be over the upper detection limit of the single count mode of CPCs of $5x10^5$ cm^{-3}. This was however not issue with our measurement setup as sample was diluted before measurement with CPCs. When dilution ratio is accounted for even the highest single PN concentration detected during the measurements by CPCs was $1.1x10^5$ cm^{-3}, which is well within the upper detection limit of our CPCs. Section 2.1.1 has been amended to mention effect of bridge diluter to CPCs specifically.

Additional dilution step was also applied for battery of condensation particle counters with bifurcated flow diluter with DR of 158 to avoid exceeding the upper detection limit of the single count mode of the condensation particle counters.

Line 430

Units are missing.

Clarification has been added to what EFs specifically are referenced when the operating temperature dependent changes in PN emissions for diesel AH are discussed. Text has been amended to read as follows:

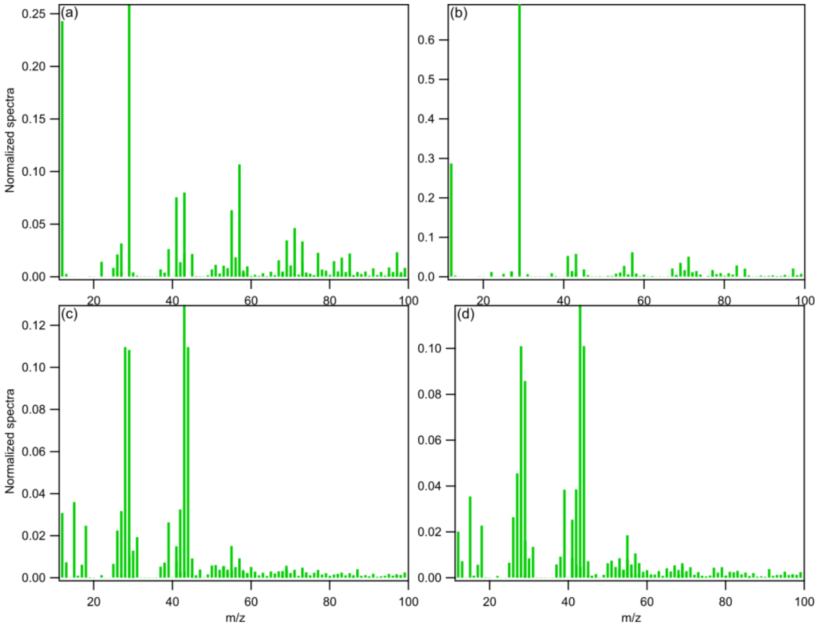
There was a slight increase in EF_{fuel} of PN>3.4 nm by a factor of 1.2 in laboratory conditions, which is almost entirely due to increases in spikes contribution to overall emissions as stable operating EF_{min} are almost zero with its ratio of laboratory to outdoor EF_{min} being only 2.3 %. For diesel, the EF_{fuel} of PN>11 nm decreased by factor of 0.44, whereas the EF_{fuel} of PN>22 nm did not change due to operating temperature change.

Figure 7

It would be interesting to show organic mass spectra, and discuss the data in detail.

Following paragraph on organic mass spectra has been added to the section 3.2.5. Figure of the spectra has also been added to the supplement.

A more detailed composition of the organic fraction can be seen in Figure S11. The fresh exhaust for both gasoline and diesel experiments are dominated by a strong signal at m/z 29 and a typical repeating pattern for hydrocarbon like organic aerosol (HOA) with signal at m/z 41, 43, 55 and 57. These results are similar to previous studies of vehicle exhaust (Mohr et al., 2009). The secondary aerosol mass spectra are similar to that of oxygenated organic aerosol (OOA) with an increased signal at m/z 44 and a clear shift to more oxygenated species. The secondary emissions are also what could be expected from secondary aerosol of vehicle exhaust (Mohr et al., 2009; Zhu et al., 2021). These results indicate that AH emissions can be difficult to distinguish from engine exhaust emissions, and for example finding a factor relating to AH emissions with positive matrix factorization could be difficult without clear differences from engine exhaust mass spectra.



Supplementary Figure 11. Normalized organic mass spectra of (a) gasoline fresh emissions, (b) diesel fresh emissions, (c) gasoline aged emissions and (d) diesel aged emissions.