

# Supplementary Material: From direct emission factors to inverse and indirect impact factors of road traffic: Influence of emerging and unregulated pollutants

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## Shares of mileages of different vehicle types and emissions classes in Finland in 2022

**Table S1: Relative shares of different vehicle types for mileages, NO<sub>x</sub> and PM<sub>2.5</sub> exhaust emissions at the studied street canyon. The values are based on the VTT's Lipasto Aliisa model 2021 results (see Table S2) and the emission factor database of the Handbook of Emission Factors for Road Transport (HBEFA version 4.1).**

Vehicle type	Mileage	NO <sub>x</sub>	PM <sub>2.5</sub>
Car gasoline	45 %	5 %	6 %
Car diesel	34 %	52 %	38 %
Van	12 %	19 %	36 %
City bus diesel	6 %	11 %	10 %
Truck without trailer	3 %	9 %	8 %
Truck with trailer	1 %	4 %	2 %
Sum	100 %	100 %	100 %

**Table S2: Shares of mileages for different vehicle types and EURO emission classes in Finland in 2022. The values are interpolated from VTT's Lipasto Aliisa model 2021 results.**

Vehicle type	EURO0	EURO1	EURO2	EURO3	EURO4	EURO5	EEV**	EURO6	PHEV***	Electric	Sum
Car gasoline	0 %	1 %	4 %	14 %	14 %	19 %	0 %	42 %	5 %	0 %	100 %
Car diesel	0 %	0 %	1 %	6 %	18 %	33 %	0 %	41 %	0 %	0 %	100 %
Van	1 %	1 %	4 %	10 %	23 %	18 %	0 %	43 %	0 %	0 %	100 %
City bus*	0 %	0 %	0 %	0 %	0 %	0 %	15 %	66 %	0 %	18 %	100 %
Truck	0 %	0 %	2 %	9 %	12 %	26 %	0 %	51 %	0 %	0 %	100 %

\*The values for buses are from the Helsinki Region Transport HSL for the Helsinki metropolitan area.

\*\*Environmentally enhanced vehicle, i.e. emission class between Euro 5 and Euro 6.

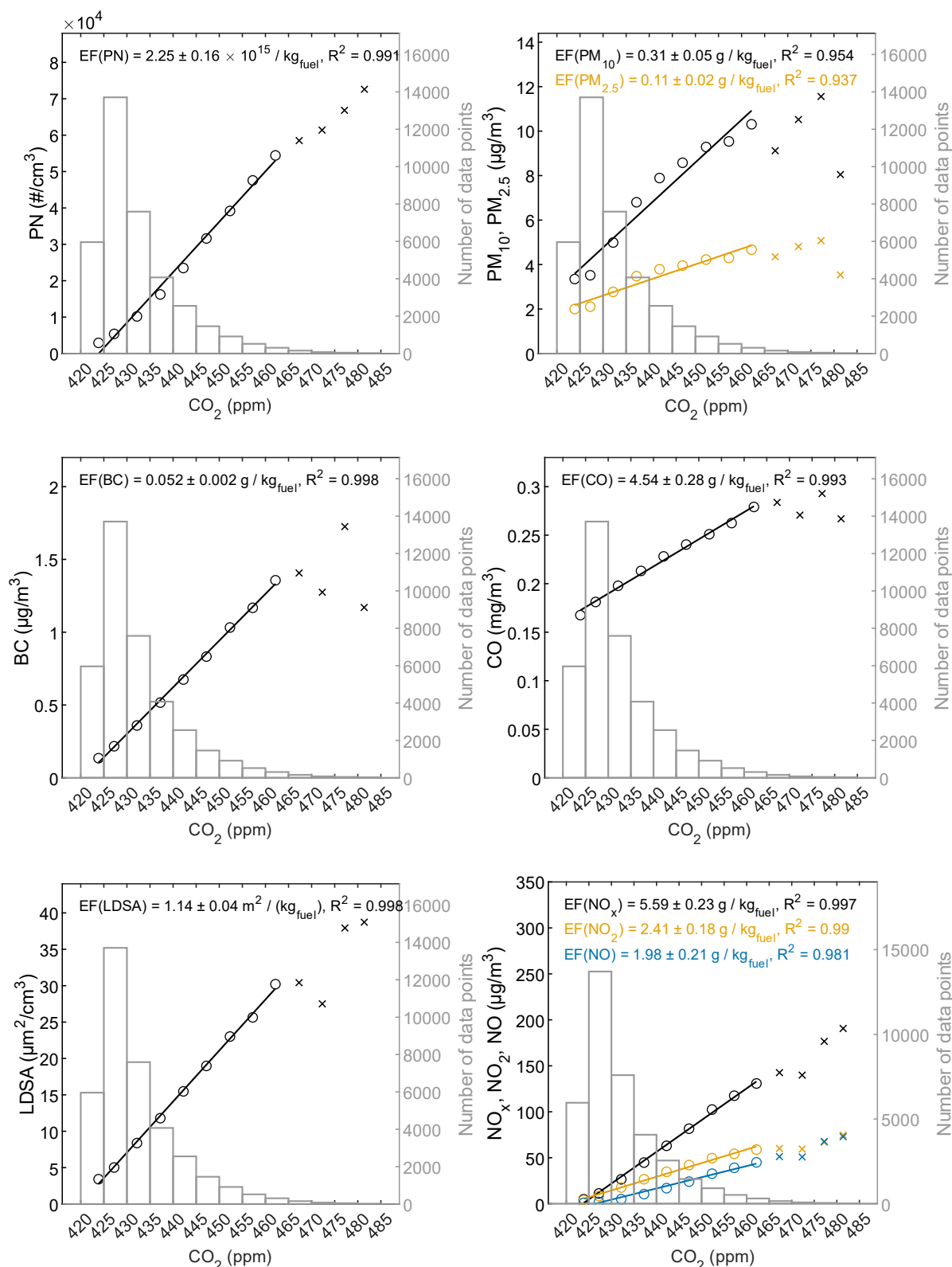
\*\*\*Plug-in hybrid electric vehicle

## Instrumentation and utilized time resolutions in the EF calculation

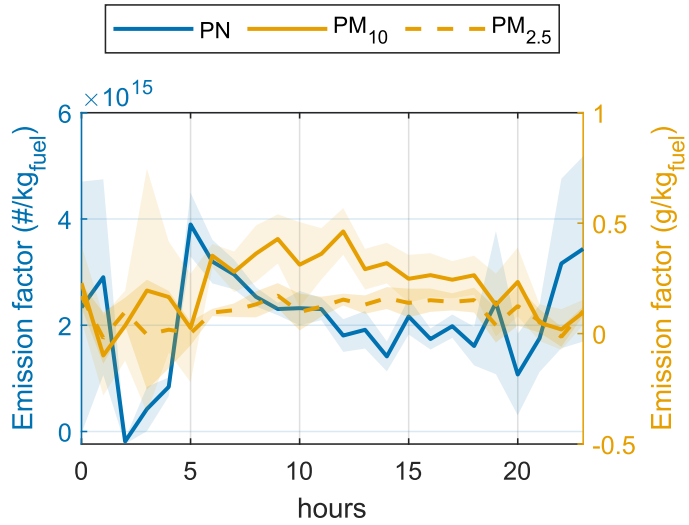
Table S3: Utilized time resolutions in the EF calculation.

<b>Instrument</b>	<b>Parameter(s)</b>	<b>Resolution in EF calculation</b>
<b>Airmodus A20</b>	PN > 5.4 nm	1 min
<b>AE33</b>	BC	1 min
<b>Fidas 200</b>	PM <sub>2.5</sub> , PM <sub>10</sub>	1 min
<b>AQ Urban</b>	LDSA	1 min
<b>APNA 370</b>	NO, NO <sub>2</sub> , NO <sub>x</sub>	1 min
<b>APMA 360</b>	CO	1 min
<b>APOA 370</b>	O <sub>3</sub>	1 min
<b>SP-AMS</b>	Organics, Nitrate, Sulfate, Ammonium, Chloride	10 min
<b>TD-GC-MS</b>	VOCs	30–45 min
<b>DMPS</b>	Particle number size distribution	60 min
<b>NAIS</b>	Particle number size distribution, ions	60 min

## Emission factors of regulated and non-regulated emerging pollutants



**Figure S1: Concentrations of PN (> 5.4 nm), PM<sub>10</sub>, PM<sub>2.5</sub>, BC, CO, LDSA, NO<sub>x</sub>, NO and NO<sub>2</sub> as a function of CO<sub>2</sub> concentration and the determined EFs, including 95 % confidence intervals and R<sup>2</sup> of the averaged linear fits. Also, the number of data points in each CO<sub>2</sub> concentration bin is shown. The pollution episodes were not included in the data.**



**Figure S2: Diurnal PN, PM<sub>10</sub>, and PM<sub>2.5</sub> EFs with 95 % confidence intervals (shaded areas). Weekends and the pollution episodes were not included in the data.**

**Table S4: Average emission factors for different vehicle types at the studied street canyon in 2022. The values are based on the VTT's Lipasto Aliisa model 2021 results (see Table S2) and the emission factor database of the Handbook of Emission Factors for Road Transport (HBEFA version 4.1).**

Vehicle type	NO <sub>x</sub> EF (g/km)	PM <sub>2.5</sub> EF (g/km)
Car gasoline	0.0648	0.0015
Car diesel	0.8291	0.0139
Van	0.8749	0.0374
City bus diesel	1.0362	0.0211
Truck without trailer	1.7632	0.0330
Truck with trailer	3.6786	0.0555
Mean	0.5447	0.0123

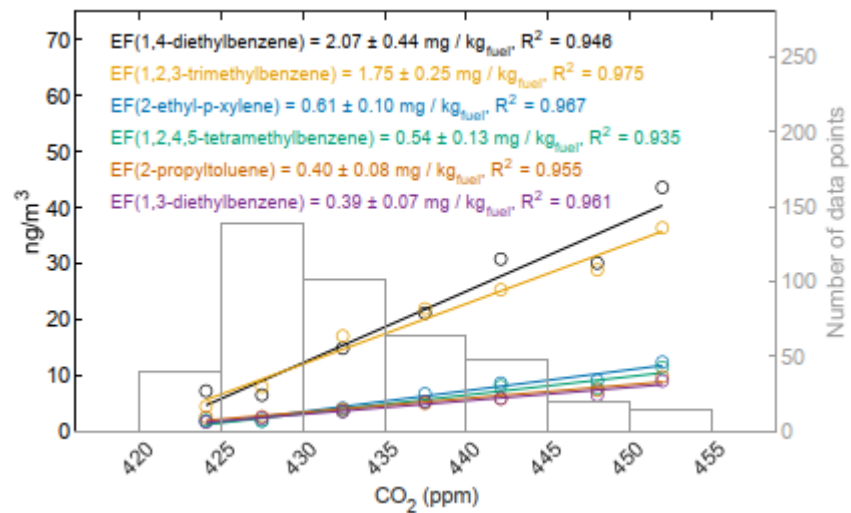
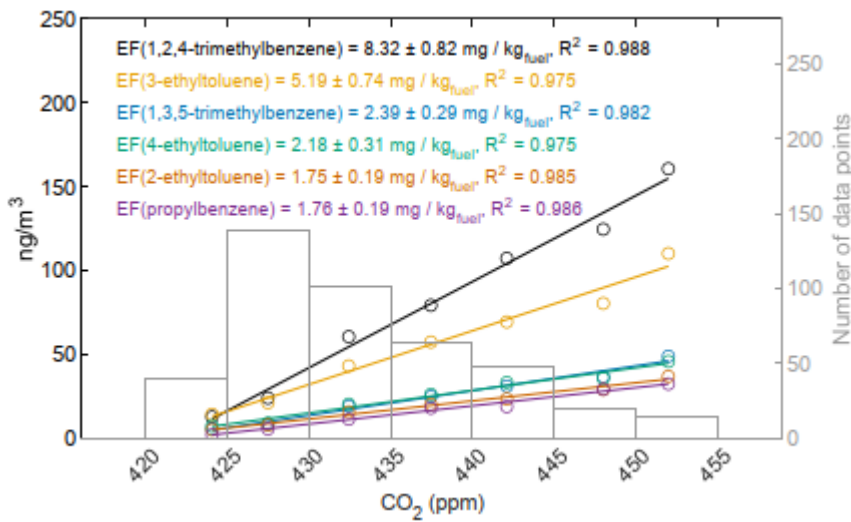
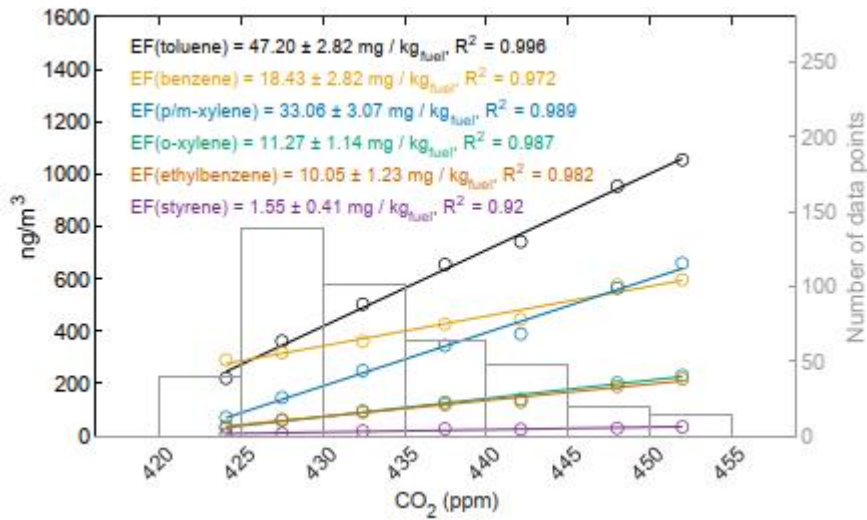


Figure S3: Concentrations of the studied aromatic hydrocarbon VOCs as a function of CO<sub>2</sub> concentration and the determined EFs, including 95 % confidence intervals and R<sup>2</sup> of the averaged linear fits. Also, the number of data points in each CO<sub>2</sub> concentration bin is shown. The pollution episodes were not included in the data. Note the varying y-axes.

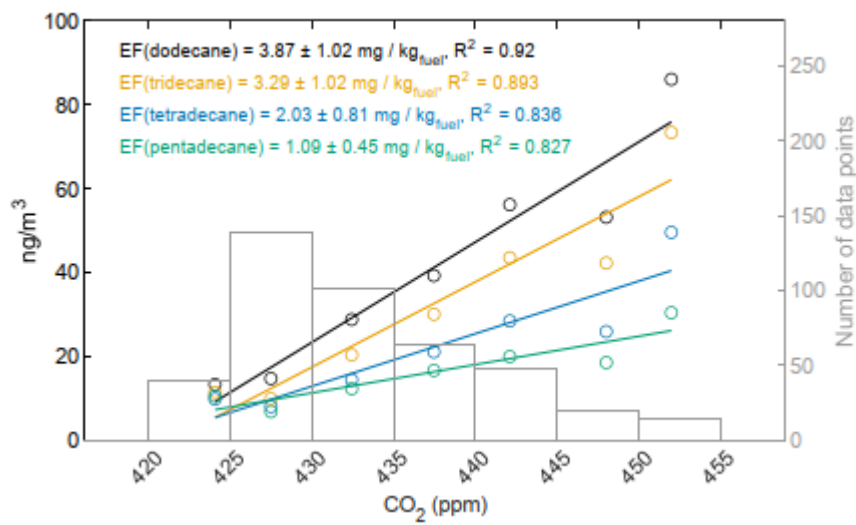
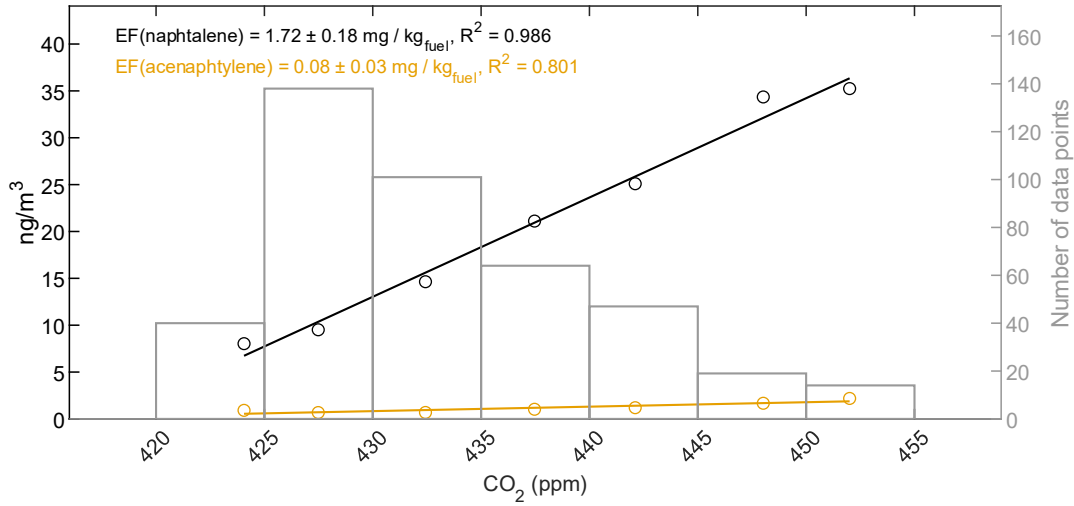
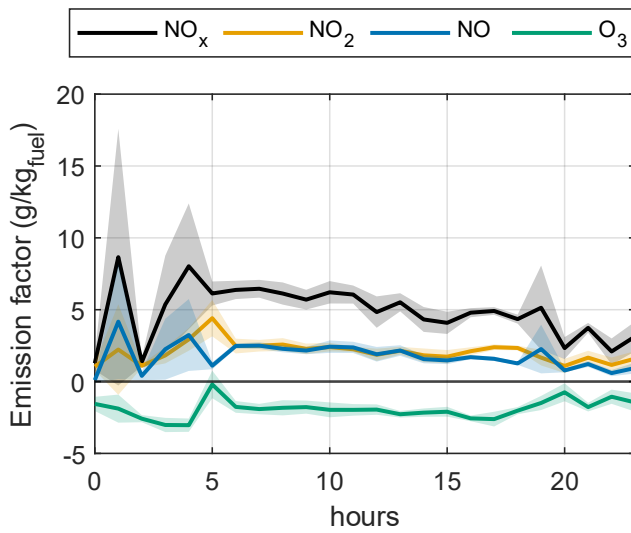


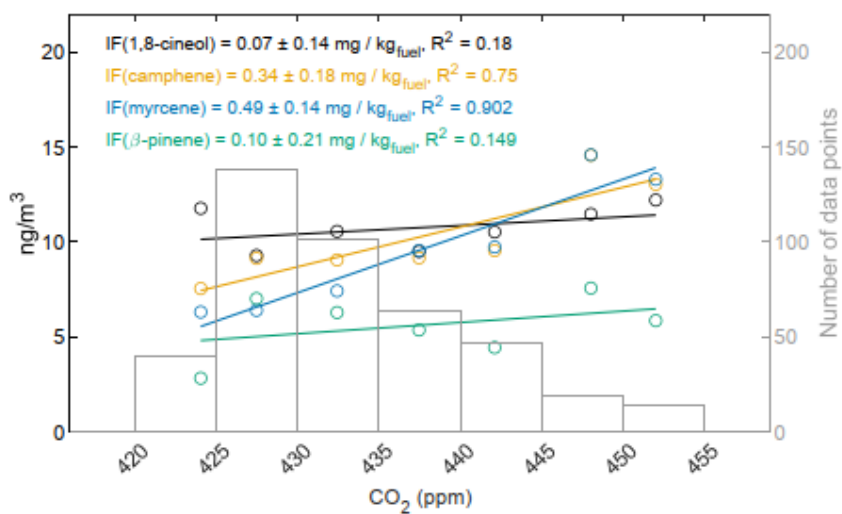
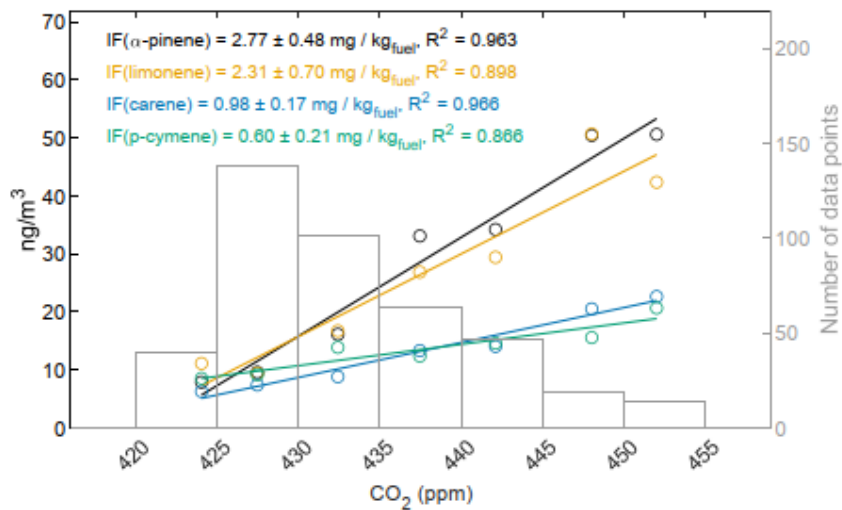
Figure S4: Concentrations of the studied alkane VOCs as a function of CO<sub>2</sub> concentration and the determined EFs, including 95 % confidence intervals and R<sup>2</sup> of the averaged linear fits. Also, the number of data points in each CO<sub>2</sub> concentration bin is shown. The pollution episodes were not included in the data. Note the varying y-axes.



**Figure S5: Concentrations of the studied gaseous PAHs as a function of CO<sub>2</sub> concentration and the determined EFs, including 95 % confidence intervals and R<sup>2</sup> of the averaged linear fits. The pollution episodes were not included in the data. Also, the number of data points in each CO<sub>2</sub> concentration bin is shown.**



**Figure S6: Diurnal NO<sub>x</sub>, NO<sub>2</sub>, NO, and O<sub>3</sub> EFs with 95 % confidence intervals (shaded areas). Weekends and the pollution episodes were not included in the data.**



**Figure S7: Concentrations of the studied terpenoid VOCs as a function of CO<sub>2</sub> concentration and the determined EFs, including 95 % confidence intervals and R<sup>2</sup> of the averaged linear fits. The pollution episodes were not included in the data. Also, the number of data points in each CO<sub>2</sub> concentration bin is shown.**

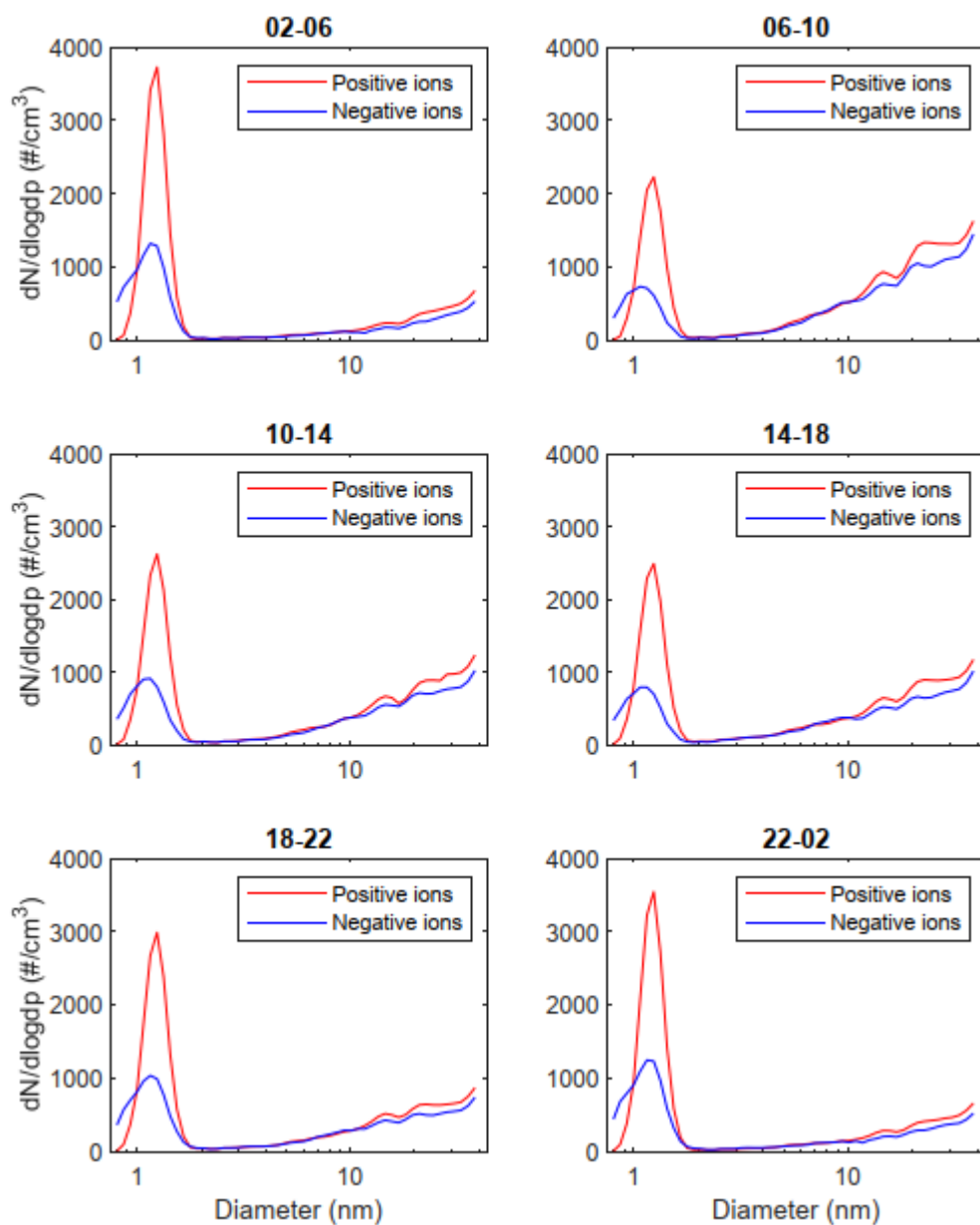


Figure S8. Size distributions of positive and negative ions during different times of the day. The pollution episodes and weekends were not included in the data.

**Table S5: Comparison of VOC EFs and IFs together with 95 % confidence intervals (CI) and the R<sup>2</sup> of the averaged linear fits during episodic and non-episodic periods.**

Class	VOC	Episodic		Non-episodic	
		EF (IF) and 95 % CI (mg / kg <sub>fuel</sub> )	R <sup>2</sup> of the averaged linear fit	EF (IF) and 95 % CI (mg / kg <sub>fuel</sub> )	R <sup>2</sup> of the averaged linear fit
<b>Aromatic hydrocarbons</b>	Benzene	43.6 ± 16.4	0.876	18.4 ± 2.8	0.972
	Toluene	36.9 ± 18.2	0.805	47.2 ± 2.8	0.996
	Ethylbenzene	7.9 ± 4.7	0.743	10.1 ± 1.2	0.982
	p/m-xylene	21.1 ± 11.2	0.765	33.1 ± 3.1	0.989
	Styrene	4.4 ± 3.7	0.590	1.6 ± 0.4	0.920
	o-xylene	9.1 ± 5.1	0.759	11.3 ± 1.1	0.987
	Propyl benzene	1.5 ± 0.9	0.719	1.8 ± 0.2	0.986
	3-ethyltoluene	3.3 ± 3.0	0.537	5.2 ± 0.7	0.975
	4-ethyltoluene	3.1 ± 2.6	0.582	2.2 ± 0.3	0.975
	1,3,5-trimethylbenzene	4.1 ± 3.8	0.543	2.4 ± 0.3	0.982
	2-ethyltoluene	3.0 ± 2.7	0.551	1.8 ± 0.2	0.985
	1,2,4-trimethylbenzene	4.6 ± 3.4	0.645	8.3 ± 0.8	0.988
	1,2,3-trimethylbenzene	1.1 ± 0.9	0.575	1.8 ± 0.3	0.975
	1,3-diethylbenzene	-0.1 ± 0.1	0.255	0.4 ± 0.1	0.761
	1,4-diethylbenzene	0.7 ± 0.4	0.752	2.1 ± 0.4	0.946
	2-propyltoluene	0.1 ± 0.1	0.611	0.4 ± 0.1	0.955
2-ethyl-p-xylene	0.2 ± 0.1	0.805	0.6 ± 0.1	0.967	
1,2,4,5-tetramethylbenzene	0.1 ± 0.2	0.280	0.5 ± 0.1	0.935	
<b>Alkanes</b>	Heptane	5.0 ± 4.3	0.582	1.5 ± 2.8	0.192
	Octane	3.3 ± 4.3	0.378	2.0 ± 2.2	0.405
	Nonane	1.5 ± 0.9	0.734	3.0 ± 0.5	0.963
	Decane	2.0 ± 1.3	0.697	6.0 ± 2.0	0.879
	Undecane	3.5 ± 0.8	0.951	5.6 ± 1.3	0.940
	Dodecane	1.8 ± 0.7	0.865	3.9 ± 1.0	0.920
	Tridecane	1.5 ± 1.0	0.705	3.3 ± 1.0	0.893
	Tetradecane	1.0 ± 0.4	0.868	2.0 ± 0.8	0.836
	Pentadecane	1.2 ± 0.5	0.826	1.1 ± 0.5	0.827
<b>Polycyclic aromatic hydrocarbons</b>	Naphtalene	1.3 ± 0.9	0.651	1.7 ± 0.2	0.986
	Acenaphthylene	0.06 ± 0.05	0.596	0.08 ± 0.03	0.801
<b>Terpenoids</b>	a-pinene	7.6 ± 5.8	0.635	2.8 ± 0.5	0.963
	Camphene	1.2 ± 1.1	0.532	0.3 ± 0.2	0.750
	Myrcene	1.7 ± 1.5	0.547	0.5 ± 0.1	0.902
	b-pinene	1.6 ± 2.5	0.285	0.1 ± 0.2	0.149
	Carene	2.1 ± 2.1	0.496	1.0 ± 0.2	0.966
	p-cymene	0.4 ± 0.8	0.230	0.6 ± 0.2	0.866
	Limonene	3.4 ± 2.2	0.706	2.3 ± 0.7	0.898
	1,8-cineol	0.8 ± 1.0	0.401	0.1 ± 0.1	0.180

Table S6: Episodic and non-episodic EFs of of PN (> 5.4 nm), PM<sub>10</sub>, PM<sub>2.5</sub>, BC, CO, LDSA, NO<sub>x</sub>, NO and NO<sub>2</sub>, together with confidence intervals (CI), and R<sup>2</sup> values of the averaged linear fits. Also, the IF of O<sub>3</sub> is shown.

Metric	Episodic		Non-episodic	
	EF (IF) and 95 % CI	R <sup>2</sup> of the averaged linear fit	EF (IF) and 95 % CI	R <sup>2</sup> of the averaged linear fit
PN > 5.4 nm (#/kg <sub>fuel</sub> )	$(1.1 \pm 0.1) \cdot 10^{15}$	0.985	$(2.3 \pm 0.2) \cdot 10^{15}$	0.991
BC (g/kg <sub>fuel</sub> )	$0.068 \pm 0.007$	0.984	$0.052 \pm 0.002$	0.998
PM <sub>10</sub> (g/kg <sub>fuel</sub> )	$0.51 \pm 0.10$	0.933	$0.31 \pm 0.05$	0.954
PM <sub>2.5</sub> (g/kg <sub>fuel</sub> )	$0.36 \pm 0.06$	0.959	$0.11 \pm 0.02$	0.937
LDSA (m <sup>2</sup> /kg <sub>fuel</sub> )	$1.12 \pm 0.08$	0.992	$1.14 \pm 0.04$	0.998
NO <sub>x</sub> (g/kg <sub>fuel</sub> )	$4.04 \pm 0.54$	0.969	$5.59 \pm 0.23$	0.997
NO <sub>2</sub> (g/kg <sub>fuel</sub> )	$1.87 \pm 0.18$	0.984	$2.41 \pm 0.18$	0.990
NO (g/kg <sub>fuel</sub> )	$1.22 \pm 0.36$	0.864	$1.98 \pm 0.21$	0.981
CO (g/kg <sub>fuel</sub> )	$7.89 \pm 0.76$	0.984	$4.54 \pm 0.28$	0.993
O <sub>3</sub> (g/kg <sub>fuel</sub> )	$-2.81 \pm 0.33$	0.976	$-2.17 \pm 0.20$	0.985

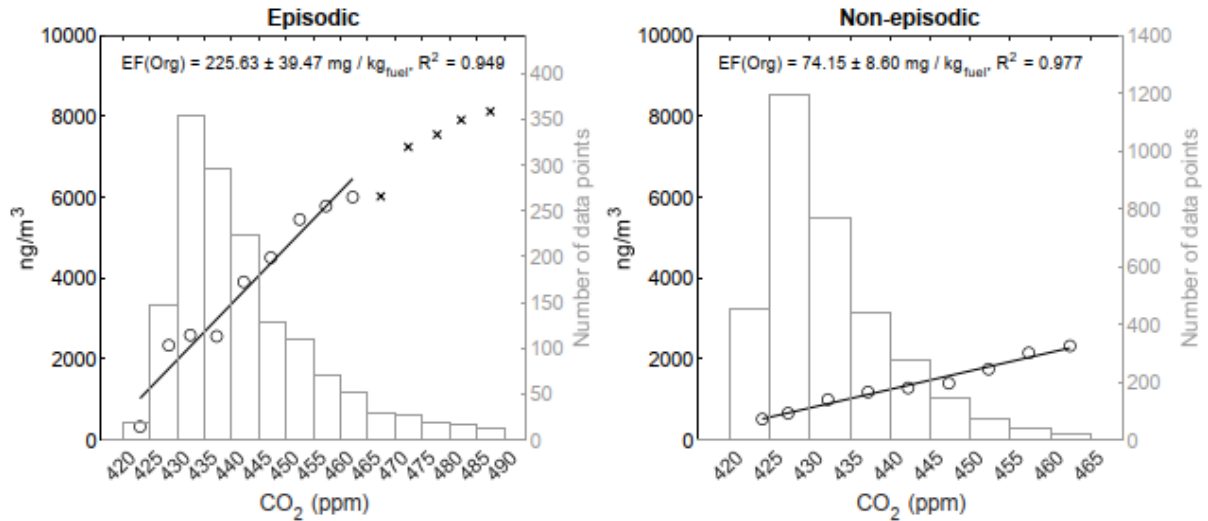


Figure S9. Episodic (left) and non-episodic (right) EFs of organics. Note the different x-axis.