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AIR QUALITY (PM_{10}) SCENARIOS RESULTING FROM THE EXPANSION OF HYDROGEN FUEL CELL ELECTRIC VEHICLE IN EMILIA-ROMAGNA (NORTHERN ITALY)

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Abstract: This study presents atmospheric PM_{10} scenarios deriving from vehicular traffic emissions in Emilia Romagna as resulting in 2030 from the growth of the Fuel Cell Electric Vehicle (FCEV) fleet in the region. Both exhaust and non-exhaust vehicular emissions are considered, evaluated according to the most up-to-date regional bottom-up emission inventory, which attributes about 60% of total primary PM_{10} traffic emissions to wear processes. processes. PM10 concentration maps for actual (2019) and 2030 scenarios are obtained by both Eulerian and Lagrangian dispersion model (CHIMERE and PMSS). Preliminary results highlight the future impact on atmospheric Preliminary results highlight the future impact on atmospheric PM_{10} from tires, brake and road surface wear produced by battery electric vehicles, due to their larger mass compared to FCEVs, which have smaller batteries and mass. These emissions will partially offset the lack of PM_{10} exhaust emissions for electric vehicles. Finally, the daily primary PM_{10} levels by traffic emissions simulated by PMSS and CHIMERE models were compared at specific sites relevant for the studied domain, i.e. the regulatory air quality monitoring stations.

Input data:

Traffic emission data: Regional emission inventory (2017), Regional vehicle fleet composition (2019), European and National studies of penetration scenarios (Motus-E, H2IT, etc…)

Meteorological data:

- 20 vertical wind and temperature profiles (WRF-ARW meteorological model)
- 12 stations of the ARPAE monitoring network

Methodology:

Total annual emission:

- 2019 scenario: top-down spatial and temporal disaggregation procedure
- 2030 scenario: bottom-up methodology

Emission factor:

- EE (exhaust emission) → COPERT 5
- NEE (non-exhaust emission) → non-linear relationship EF and vehicle mass, Beddows et al. (2021)

Emissions factors for PM_{10} non-exhaust emission used for 2030 scenario

PM_{10} emission factors for NEE in mg km^{-1} vehic^{-1} by vehicle type, i.e. Passenger Cars, BUS+HDV, Road Tractors:

- PC: 25.5 ICE, 24.4 BEV, 22.8 HEV and 21.7 FCEV
- BUS: 112.3 ICE, 128.4 BEV and 112.6 FCEV
- RT: 120 ICE, 135.2 BEV and 118.6 FCEV

Change in total annual emissions over 2019-2030

EXHAUST

- PC: ↓in 2030 respect to 2019 of 52.4%: 347 (2019) ⟶ 178 Mg yr^{-1} (2030) due to↑ in BEV and FCEV
- HDV+BUS: ↓of 26.6%: 357 (2019) ⟶ 262 Mg yr^{-1}(2030)

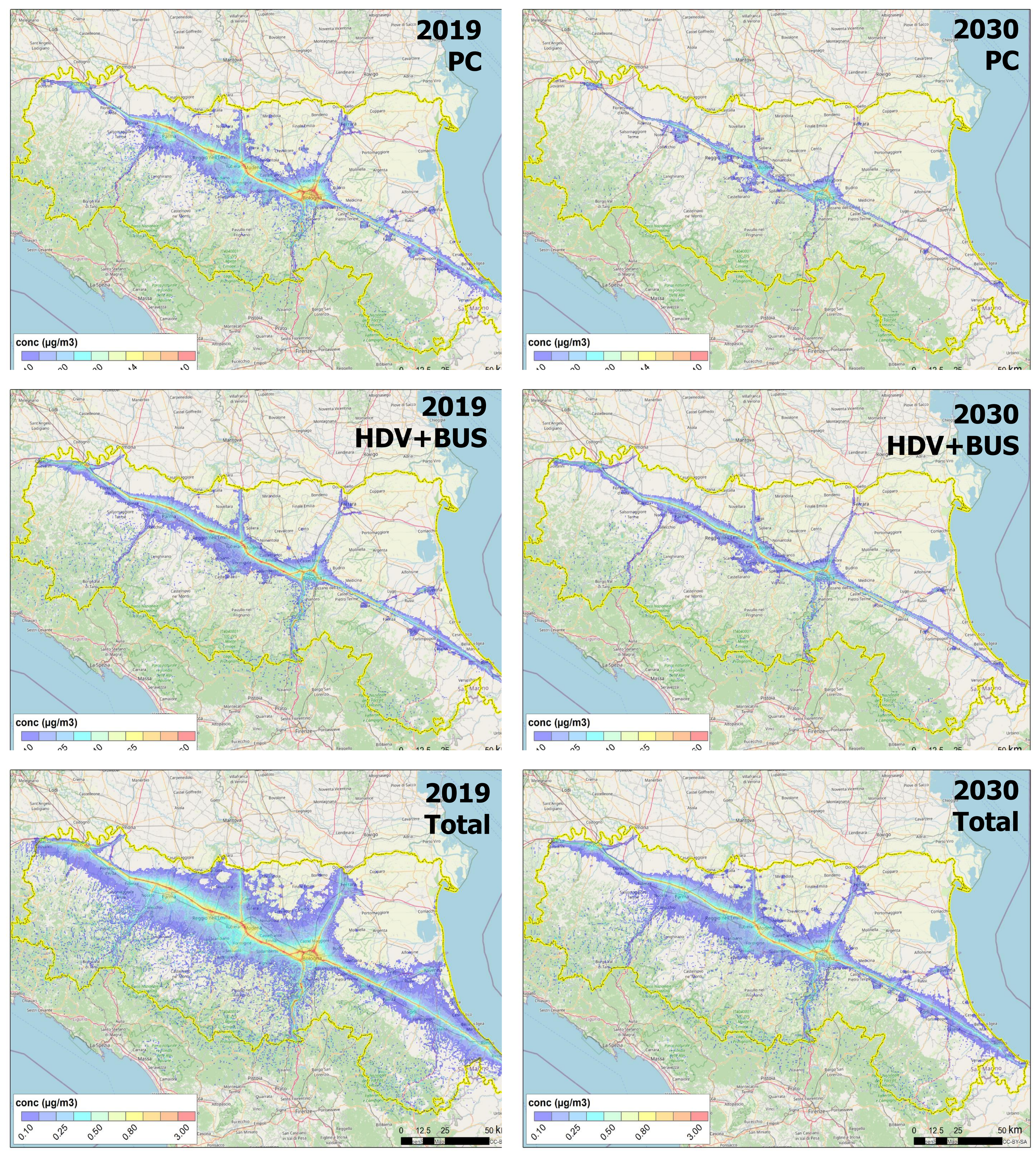
NON-EXHAUST

- PC: 1003 Mg yr^{-1} (2030, 40% efficiency of the RBS) ↔ 1009 Mg yr^{-1} (2019),↑ the mass of the vehicle fleet
- HDV+BUS: ↑of 0.6%: 349 (2019) ⟶ 351 Mg yr^{-1} (2030)

TOTAL PM_{10} traffic emissions ↓ of 13%, **2062** Mg yr^{-1} (2019) ⟶ **1794** Mg yr^{-1} (2030)

PM_{10} concentration maps

Simulation maps of atmospheric concentration for February 15 of primary PM_{10} at the ground level (4 m) due to ***exhaust emissions*** for the 2019 and the 2030 scenarios are presented in the figure on the right, for PC (top) , HDV+BUS (middle) and Total (bottom). These maps highlight a large decrease in PM_{10} concentration in the future scenario, particularly along the main motorway, the major roads and main urban areas. The qualitative comparison between the concentration maps for PC clearly shows the benefit on air quality of the renewal of the PC fleet. A decrease in concentration occurred, albeit minor, also for HDV+BUS, contributing to the overall improvement of air quality. The variation in PM_{10} levels due to changes in **NEE** between the two scenarios is negligible for both PC and HDV+BUS.



Primary PM_{10} at ground level (i.e. the first 4 m from the ground) due to **EE** by Passenger Cars (PC), Heavy Duty Vehicles + bus + road tractors (HDV+BUS), and their total, on Feb 15 in 2019 (left) and 2030 (right).

Evaluation of the model simulations performance

PMSS

Extraction hourly time series of primary PM_{10} due to traffic (EE and NEE) simulated by PMSS (500 x 500 m^2 horizontal resolution) at the 51 air quality regulatory stations

⇩

Average to daily PM_{10} (Directive EC 50/2008)

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PMSS average daily PM_{10} were compared with CHIMERE average daily PM_{10}

⇧

CHIMERE

Daily primary PM_{10} by traffic according to CHIMERE

⇧

Extraction primary PM_{10} traffic emissions from CHIMERE-simulated primary anthropogenic PM_{10}

⇧

21% urban, 15% suburban, 10.5% rural/clean suburban and 6% remote sites

⇧

Analysis of the regional emission inventory: % PM_{10} traffic emissions (EE+NEE) of total PM_{10} anthropogenic emissions

Linear correlation (*r Pearson's index*) between PMSS and CHIMERE at the air quality sites is larger or equal than 0.50 at 28 sites out of 51 over the period Feb 9 – 24, the number of sites increases to 48 if the central period of the simulation is considered (9 – 24 Feb 2019). The correlation is largest at rural sites, likely due to the inability of CHIMERE in reproducing traffic peaks in urban areas.

RMSE, MAE and **NMB** (using CHIMERE model as a reference): the difference in RMSE and MAE increases from rural (median RMSE = 0.17 µg m^{-3}, median MAE = 0.13 µg m^{-3}) to urban sites (median RMSE = 0.63 µg m^{-3}, median MAE = 0.49 µg m^{-3}). The median NMB is of 0.56 µg m^{-3} at urban sites and resulting in a median NMB and a mean NMB of –0.24 µg m^{-3} and 0.14 µg m^{-3}, respectively, on the rural sites.

Station name	Type	*r* 1 – 28 Feb	*r* 9 – 24 Feb	Station name	Type	*r* 1 – 28 Feb	*r* 9 – 24 Feb
Bogolese	urb	0.39	0.74	Timavo	urb	0.44	0.75
Cabina Mainsite	urb	0.15	0.39	Via Chiarini	urb	0.38	0.75
Caorle	urb	0.67	0.75	Villa Fulvia	urb	0.62	0.75
Ceno	urb	0.22	0.51	Zalamella	urb	0.74	0.80
Cittadella	urb	0.42	0.78	Castellarano	sub	0.62	0.76
De Amicis	urb	0.62	0.79	Cento	sub	0.74	0.82
Flaminia	urb	0.81	0.78	Remesina	sub	0.76	0.85
Franchini-Angeloni	urb	0.80	0.80	Badia	rur	0.61	0.79
Gerbido	urb	0.39	0.58	Besenzone	rur	0.44	0.34
Giardini	urb	0.73	0.87	Cabina Molinella	rur	0.70	0.73
Giardini Margherita	urb	0.11	0.37	Delta Cervia	rur	0.70	0.61
Giordani-Farnese	urb	0.48	0.73	Gavello	rur	0.50	0.51
Isonzo	urb	0.75	0.84	Gherardi	rur	0.59	0.56
Marecchia	urb	0.75	0.68	Lugagnano	rur	0.45	0.60
Montebello	urb	0.32	0.75	Malcantone	rur	0.58	0.61
Paradigna	urb	0.20	0.71	S. Rocco	rur	0.68	0.75
Parco Bertozzi	urb	0.68	0.82	San Pietro Capof.	rur	0.69	0.74
Parco Edilcarani	urb	0.56	0.82	Saragat	rur	0.41	0.55
Parco Ferrari	urb	0.78	0.87	Savignano	rur	0.82	0.77
Parco Montecucco	urb	0.51	0.65	Verucchio	rur	0.71	0.72
Parco Resistenza	urb	0.29	0.74	Castelluccio	rem	0.48	0.73
Porta San Felice	urb	0.36	0.61	Corte Brugnatella	rem	0.40	0.55
Roma	urb	0.40	0.71	Febbio	rem	0.41	0.68
S. Lazzaro	urb	0.46	0.82	San Leo	rem	0.71	0.71
San Francesco	urb	0.43	0.81	Savignano di Rigo	rem	0.51	0.67
San Lazzaro	urb	0.14	0.66				

Pearson's correlation coefficient (r) between PMSS and CHIMERE primary PM10 due to traffic emission at ARPAE station sites. "urb" urban, "sub" suburban, "rur" rural and clean suburban sites, "rem" remote sites

Conclusions:

a future emissive scenario (2030), in which the introduction of a large number of BEVs and FCEVs in the vehicle fleet is expected, is compared with the current one, referring to 2019. The renewal of the fleet brings a clear benefit to air quality, due to the reduction of exhaust emissions. Regarding non-exhaust emissions, no substantial differences are observed between the two scenarios, however the lower mass (by ~20%) of FCEVs compared to BEVs results in lower non-exhaust PM10 emission factors. The average daily concentrations of primary PM10 from traffic emissions (exhaust and non-exhaust) calculated by PMSS were compared with those calculated by CHIMERE over a focus period (February 2019) at regulatory air quality monitoring sites. The models show good agreement in the temporal behaviour of the concentrations, showing the effectiveness of the simulation obtained from PMSS. The analysis of the data highlights the potential capacity of the PMSS to simulate the dispersion of primary pollutants on urban areas. Larger estimates of PM10 by PMSS are observed in most urban sites and only in half of rural sites, providing conflicting results for this type of site in part due to the higher spatial resolution of PMSS.

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