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ATMOSPHERIC IMPACT OF POWER PLANT STACK EMISSIONS

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Abstract: The atmospheric impact of stack emissions from a tri-generation power plant that will be installed in an urban area in the central Po valley are studied and compared to the impact of the existing plant (conventional boilers). Both plants are supplied by methane gas. The atmospheric dispersion of the emissions is simulated both in the current and the future scenario, i.e. before and after tri-generation plant activation respectively. The plant is assumed as a continuous emission point source. The emission rates are set equal to the regulatory emission limits for the existing plant and to the emission limits certified by the tri-generation system manufacturer for the future plant. The local meteorological, topographical and surface land cover datasets have been used. The simulation periods span over each one of the four seasons, using 2010 meteorological data, to test conditions (favourable and adverse) to pollutant accumulation in the atmosphere; simulation with period spanning over the whole 2010 year are also performed (long-term). The dispersion of different air pollutants (NO_x mainly) is presented; the concentration fields obtained for the same period in the two different scenarios are compared. The aim of the simulation is to estimate the impact of emissions on air quality in the urban area close to the plant, in different weather conditions, in a region characterized by calm wind events. The simulation is performed by the software package ARIA INDUSTRY, that is made up of the 3D lagrangian stochastic particle dispersion model SPRAY(Arianet, 2007b; Tinarelli et al., 1998; Thomson, 1987), the diagnostic meteorological model MINERVE (Geai, 1987; ARIA Tech., 2001) and the turbulence model SURFPRO(Arianet, 2007a).

Current scenario

The current Central Heating of the General Hospital includes five generators (conventional boilers) supplied by methane gas, with a total nominal power of 20.109 MW. Usually only three of the five boilers operate continuously. The total mass of pollutant, actually emitted in one year by the existing plant has been estimated from the annual fuel consumption of the year 2010. The plant is assumed to operate at the maximum daily fuel consumption for year 2010 (22 143 Nm^3/d) and the emissions are set equal to regulatory limits. This operating mode is indicated as the "calculated" operating conditions. The regulatory limits for emissions of methane supplied boiler with a nominal power lower than 50 MW are (D.L. 152/06 and Local Administration for CO limits): NOx (as NO2) = 350 mg/Nm^3, SOx = 35 mg/Nm^3, PM10 = mg/Nm^3, CO = 100 mg/Nm^3 with 3% O2.

Future scenario

This tri-generation plant will be a Jenbacher JMS 620 GS-N.L, whose approved electrical power is 3 349 kWe and thermal power 3 098 kW, with an internal combustion four-stroke engine powered by methane gas. The tri-generation plant stack, at nominal operating conditions, will emit in the atmosphere a dry gas flow of 13 920 Nm^3/h with 11.2% O_2. The regulatory limits for atmospheric emissions of internal combustion four-stroke engine are set by Italian law (D.L. 152/06): NO_x (as NO_2)=500 mg/Nm^3, CO=650 mg/Nm^3, PM10=130 mg/Nm^3 with 5% O_2. The tri-generation plant manufacturer certifies the following emission rates: NO_x (as NO_2) ≤ 250 mg/Nm^3, CO ≤ 300 mg/Nm^3, PM10 ≤ 30 mg/Nm^3.

The electric energy that must still be supplied from the Italian Electric Energy Network (IEEN) is 4 013 MWh/y in the future scenario and 25 494 MWh/y in the current scenario. This will lead to a reduction in emissions from electric energy production due to avoided emissions, although the direct atmospheric emissions rate from the tri-generation plant is higher than the current one. Side table shows the annual mass fluxes for the two plants for each pollutant.

Pollutant	Tri-generation plant	Existing plant
	Annual atmospheric emission (t/y)	
NO_X	14.94	10.62
CO	17.93	3.03
SOx	/	1.06
PM10	1.79	0.15
CO_2	11 347	5 865

STUDIED DOMAINS AND DATA SET

Spatial domain for diagnostic wind field
Extension: 40 km x 40 km
SW corner (634 106 m East; 4 924 131 m North) (UTM-WGS84).
Horizontal resolution: 500 m
Top domain: 1800 m

Computation of pollutants concentration field
Extension: 20 km x 20 km
Horizontal resolution: 250 m

Period simulation
2010

Source emission
The Central Heating of the General Hospital and the tri-generation future plant.

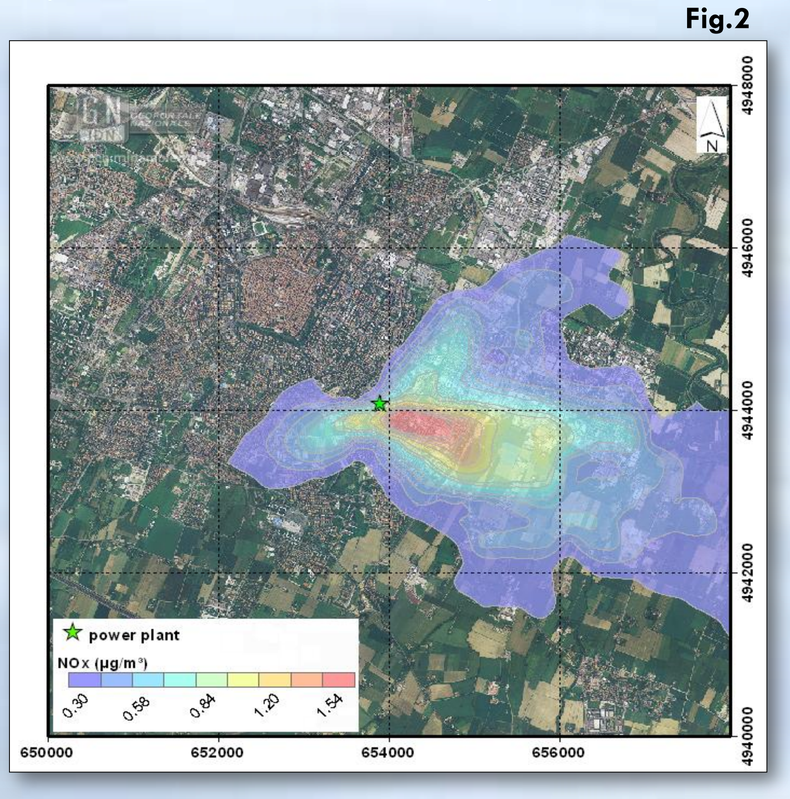
Data meteorological
Osservatorio Geofisico of the University of Modena and Reggio Emilia, ARPA and CALMET model.

Data territorial
DEM from Shuttle Radar Topography Mission and European CORINE Land Cover 2000 dataset (EEA).

RESULTS

Only NO_x concentration maps are reported and discussed in this study, being the most critical pollutant for methane fuelled plant.
To represent the maximum impact case, the tri-generation plant is assumed to operate stationary at its nominal conditions, while the current plant is assumed to operate at the "calculated" condition. The winter season simulation was characterized by meteorological conditions favorable to pollutant accumulation in the atmosphere.

Fig.2



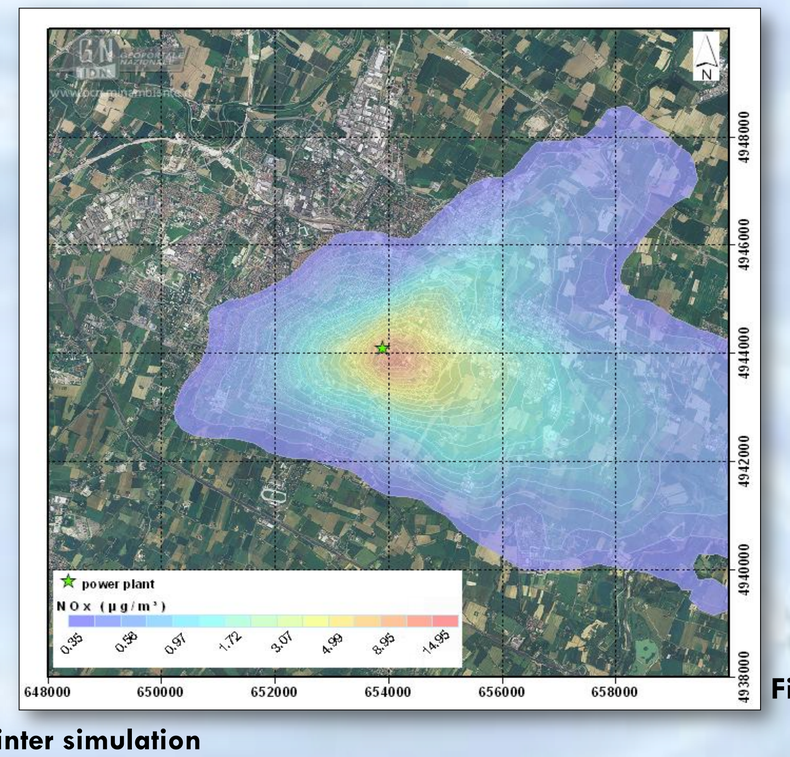


Fig.1

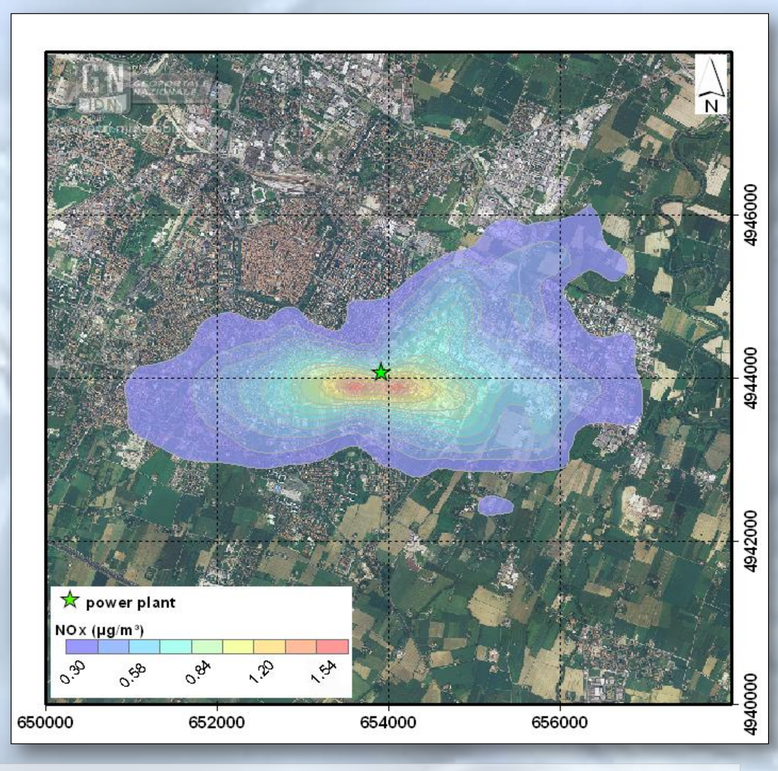
Winter simulation

Simulation period ranges from January 1st to March 20th 2010.
In the current scenario, the average NO_x concentration values in winter ranges from 0.35 to about 15 $\mu g/Nm^3$ (Fig.1). In the future scenario the highest concentration values are lower than 1.6 $\mu g/Nm^3$ (Fig.2). Assuming the average winter daily fuel consumption value for the current plant (14 578 Nm^3) instead of the maximum, atmospheric NO_x concentration would be ~20% lower. However, there is a wide difference between the two plant operating conditions, as shown in figures 1 and 2. In other seasons, the fuel consumption from the current plant is lower than in winter, leading to a lower impact on air quality.

Annual simulation

The emission flow from the tri-generation plant is expected to be quite steady throughout the year, in effect the highest concentration values are lower than 1.6 $\mu g/Nm^3$ (Fig.3). The stack emissions of the tri-generation plant, although in late spring and summer are higher than the current plant emissions, will not impact significantly local air quality, due to the better atmospheric mixing during the warmer season.

Fig.3



CONCLUSIONS

The self production of electric energy by the tri-generation plant enables to avoid the emissions due to the electric energy generation, although this reduction in emission will not affect local air quality, but the area surrounding electric power plants of the national network. The annual stack emission in the atmosphere, evaluated as total mass flux of pollutants, results higher for the tri-generation plant than for the current plant.
No_x proved the influence of the different operating mode of the two plants in affecting local air quality. The current plant emissions have a strong seasonality and in winter they may lead to NO_x local concentration close to the regulatory limits. The stack emissions from the tri-generation plant will be fairly steady throughout the year, resulting lower than current plant emission in winter and early autumn, but higher in late spring and summer season. In spite of this, the simulation shows that the emissions from the tri-generation plant do not influence significantly local air quality in any season of the year, because of the its steady operating condition.

Reference

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