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Modelling and evaluation of emission scenarios deriving from wood biomass boilers in alpine valley

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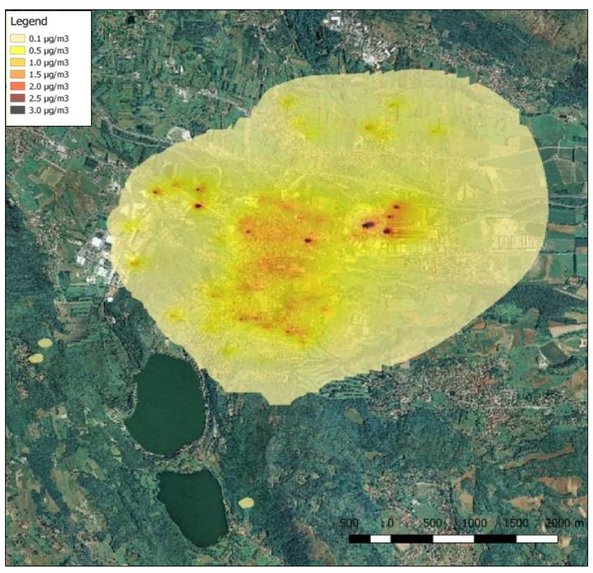
Introduction

In recent years there has been a growing spread of the use of renewable energy sources. A sharp increase of consumptions concerns the wood biomass.
Assuming that the timber consumption is suitably regulated by the forest management policies, the environmental impact of these systems is almost fully linked to pollutant emissions in the atmosphere. There are two main pollutant emissions related to the use of wood biomass as a fuel: release of combustion products from the heating systems and of pollutants from the vehicles transporting the wood.
The most significant pollutants resulting from the installation of these plants are PM, NO_X and SO_2. In particular according the literature analysis, particulate matter emissions are particularly critical. The impact of these systems in regions where atmospheric PM concentrations are significant must be carefully assessed.
The aim of the study is the assessment of the impacts on PM concentrations of a network of wood biomass heating systems located within an alpine valley in the north of Italy. The objective is the assessment of the hypothesis of the progressive replacement of traditional fossil fuel boilers with wood biomass boilers. In particular, the aim of the present research is, starting from already published results, to observe how the results can be influenced changing some input data and how this modification can be considered in order to better understand the issue and improve the design hypothesis.

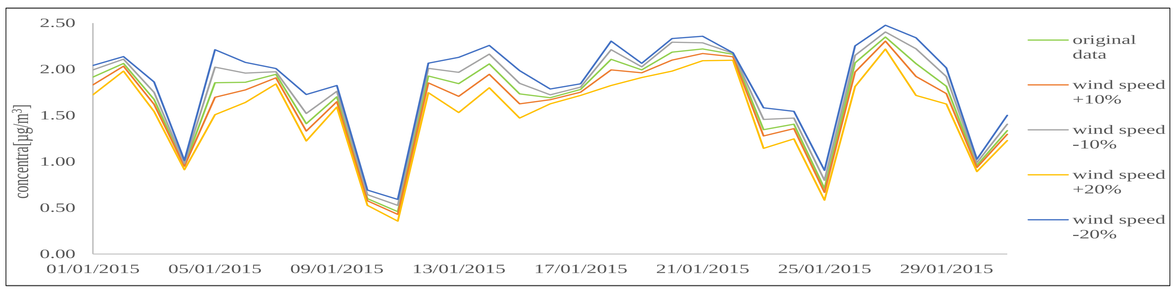
Method

The first phase of research has identified the emission scenarios that could best approximate the assumption of complete replacement of the current fossil fuel heating network. To estimate the air concentration of PM at ground level, simulations of atmospheric dispersion have been performed with the model SIRANE. It is conceived to simulate pollutant dispersion emitted from line sources (e.g. traffic emissions) and punctual sources (e.g. chimneys) at a local scale. The chosen sample area is located at the entrance of an alpine valley in the North West of Italy. The analysis is performed using the meteorological data for the year 2015.
In order to observe how the influence of varying operating conditions can affect air pollutant concentrations, different scenarios have been analysed assuming different hypothetical modes of operation. The key parameter is the emissions, which can be changed between full and partial load. The turnover between the two mode is assumed according to different hypothesis. The mode of functioning can be assumed a priori, with the same turnover regardless the external temperatures or keeping into account this factor.
The objective of the present work is to observe how modification of the input data can influence the results and how this parameters haves to be considered during the definition of the design hypothesis. In order to do so, first a sensitivity analysis has been done in order to observe how the results were influenced by the input data. After, some design hypothesis have been modified in order to determine their influence on the results.

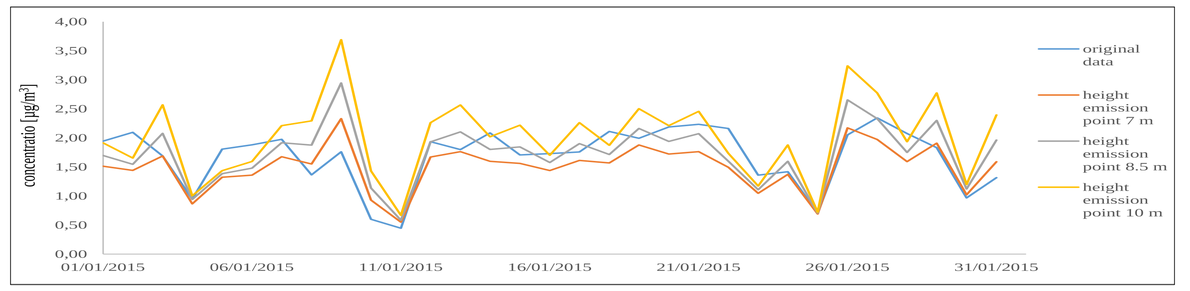
Results



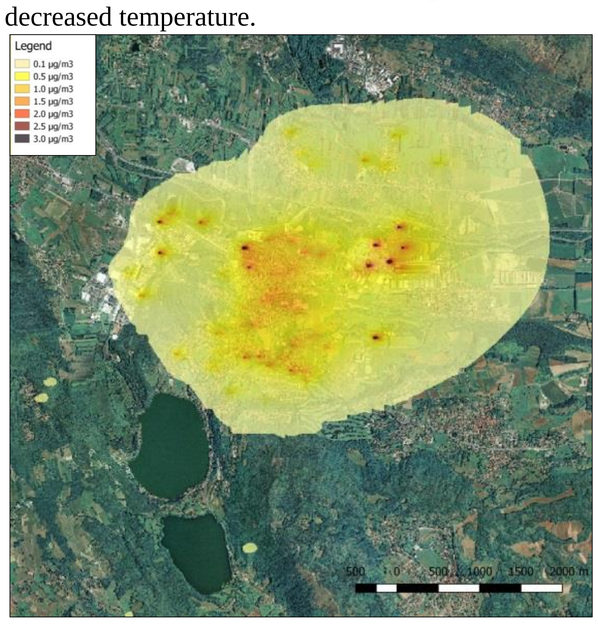
The figure shows the results obtained through the modeling of the emission scenario determined by the substitution of the whole traditional fuel heating network with wood biomass boilers.
The period considered for the modeling is the month of January 2015. The emissions were considered to be influenced by the external temperature, namely the turnover is not constant but influenced by the temperatures. It can be observed how the concentration level are not very significant if compared with the limiting value (40 µg/m^3) indicated by the European legislation for PM_{10}. However, these emissions have to be considered as an additional factor comparing with the existing pollutants emissions in a territory. Hence, they cannot be considered as not important, also considering that traditional fuel emissions of PM are negligible.
Meteorological data that are considered most significant for the purpose of a sensitivity analysis are solar radiation and wind speed. Therefore, additional modeling have been done for the month of January. With regard to the solar radiation, in the modeling carried out, there are no significant changes both as regards the concentration maps that the trend of the concentration values in correspondence of the receptors.
The figure shows that the influence of wind speed on the concentration values is inversely proportional.

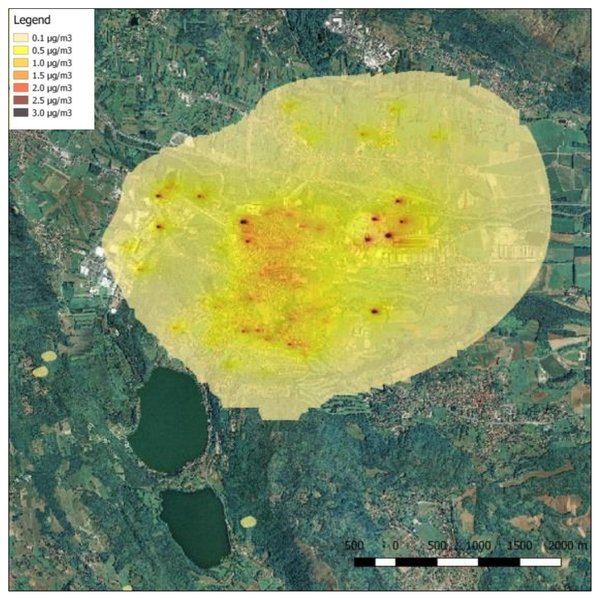


Another significant parameter for the dispersion process is the height of the emission point. The input data have been modified by imposing different constant heights of the boilers emission points. In the receptor concentration trends there are higher values in the hypothesis of higher emission points .

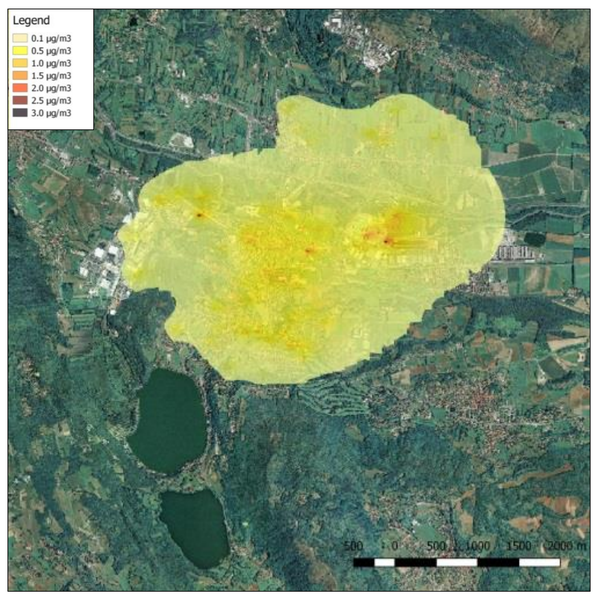


To observe how the emissive scenario is influenced by variations of the outside temperature a sensitivity analysis was carried out. The temperature input has been therefore varied increasing and decreasing them respectively of 2 °C. The modulation of the boiler, and consequently the emissions, has been varied according to these variations. The figures show respectively the concentration map with increased and decreased temperature.





In the starting hypothesis, a medium energy performance of the buildings (D) was assumed in order to determine the size and the numbers of boilers needed to guarantee the energy demands.



It can be assumed that greater sustainability would be reached in a perspective of improvement of buildings energy performance that would result in a significant reduction in emissions.
This scenario is compatible with the bonus policies of such improvements currently present. Such a scenario is conceivable only if accompanied by the installation of solar panel for the production of sanitary hot water for the summer period.
In this scenario, the heat demand was calculated assuming an energy class of the buildings significantly better (B). Based on this value, the size of the installed boilers has been changed and the power reduced.
The figure shows the concentration map obtained for the month of January in the hypothesis of improvement of building energy classification.

Conclusion

The obtained results beyond allowing to observe how the modification of the input data influences the results, show how is not easy to determine the influence of one parameter on the results and how this has to be considered during the design hypothesis. The design of these systems have to consider different factors to obtain a solution really compatible with the environment and energetic efficient.
The features of renewability and availability of wood biomass determine a growing interest in this source of energy. However, the results show how environmentally sustainable results can be achieved only coupling these systems with other renewable source of energy and moving towards an improvement of the energy performance of the buildings.

References

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