



## **Estimating domestic wood burning emissions in Nordic countries using ambient air observations, receptor and dispersion modelling**

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One of the major emission sources of primary PM<sub>2.5</sub> in Nordic countries during winter is wood burning from domestic heating. In Norway alone it is estimated that 80% of PM<sub>2.5</sub> is emitted through this source. Though direct measurements of wood burning emissions are possible under controlled conditions, emission inventories for domestic heating are difficult to calculate. Emissions vary from stove to stove as well as wood type, wood condition and burning habits. The consumption rate of wood burning is also strongly dependent on meteorological as well as societal conditions. As a result the uncertainty in wood burning emission inventories used in dispersion modelling is considered to be quite high.

As an alternative method for estimating the emissions resulting from wood burning for domestic heating this paper combines ambient air measurements, chemical analysis of filter samples, receptor models, dispersion models, and simple inverse modelling methods to infer emission strengths. The methodology is applied in three Nordic cities, notably Oslo (Norway), Helsinki (Finland) and Lycksele (Sweden). In these cities daily filter samples over several months have been collected. The filter samples have been chemically analysed for a range of elemental and specific markers including OC/EC and Levoglucosan. The chemical analysis has been used as input for a range of receptor models, including UNMIX, PMF, PMF-2 and COPREM. From these calculations the source contributions at the measurement sites, with particular emphasis on wood burning, have been estimated. Though the receptor models have a common basis their application method varies, and as a result the number of identifiable sources and their contributions may differ. For the application here the contribution of wood burning was not found to vary significantly, irrespective of the model or user. It was also found that Levoglucosan as a wood burning tracer was essential for the identification of the wood burning sources.

Source apportionment studies based on chemical analysis and receptor modelling provide source contributions at the receptor site only. To relate these to emissions dispersion models are required. The source contribution of wood burning calculated with dispersion models is compared, at the receptor site, with the receptor model results. This comparison shows that in Oslo and Lycksele the dispersion models provide higher estimates, factor of two or more, for the contribution of wood burning to PM<sub>2.5</sub> than do the receptor models. To further assess the differences between the receptor and dispersion modelling a simple inverse modelling technique, using multiple linear regression, is applied to the total PM<sub>2.5</sub> concentrations, measured at all monitoring stations, to assess the contribution of wood burning. The inverse modelling results have been found to agree with those from the receptor modelling for both Oslo and Lycksele. Though both the receptor and inverse modelling calculations indicate an overestimation of the wood burning emission rates for PM<sub>2.5</sub> it is not possible to assign this solely to errors in the existing emission inventories as dispersion model uncertainty may also be significant. To improve this situation it is recommended to improve plume rise and urban canopy meteorological descriptions in the dispersion models so that these models will be of sufficient quality to allow quantitative assessments of emission inventories.