ESTIMATING VOC EMISSIONS FROM RESIDENTIAL BIOMASS COMBUSTION IN FINLAND

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One of the most significant non methane volatile organic compounds (NMVOC) emission sources in Finland is residential wood combustion. It contributed to 27.2 kton(NMVOC)/a (17% of total NMVOC emissions) in 2000 according to present emission inventories, that comprise only one wood use volume and international default emission factor for the residential combustion sector. However, residential combustion takes place in various types of equipment, e.g. small boilers, stoves, masonry ovens, kitchen ranges, sauna stoves, open fireplaces etc., and emission factors vary widely depending on furnace type, fuel characteristics, time of the year and operating parameters.

In this paper wood use volumes and NMVOC emission factors were estimated to 10 different residential combustion equipment categories based on literature sources. Influence of operating parameters and fuel quality was investigated.

Reported emission factors from residential combustion varied from 0 to 1700 mg (NMVOC)/MJ. Emission estimate of this study was significantly lower than the estimate in the current inventory.

The results of this study show how important detailed information on national characteristics of residential wood combustion is in order to achieve satisfying accuracy on emission estimates. In means of understanding nature and volume of VOC emissions from domestic sector well documented sensitivity study on this area in order to perceive error estimates in country level.

The results will be used to refine national emission inventories and assess the background material included in the ongoing revisions of air pollution agreements in Europe.

INTRODUCTION

Wood combustion in the residential sector, i.e. in residential and recreational houses, is relatively common in Finland. Approximately 20% of the detached houses and almost all recreational houses are heated primarily with wood. In addition, majority of detached houses has a fireplace as secondary heat source. Total number of fireplaces is estimated to be 2.2 million, of which 1.2 million are in detached houses, 0.8 million in summer cottages [1]. So far there is no legislation on emission limits of fireplaces or small boilers in Finland.

Totally domestic combustion accounts according emission inventories 17% of total VOC in Finland. A pie chart in figure 1 describes shares of different emission sources in Finland.

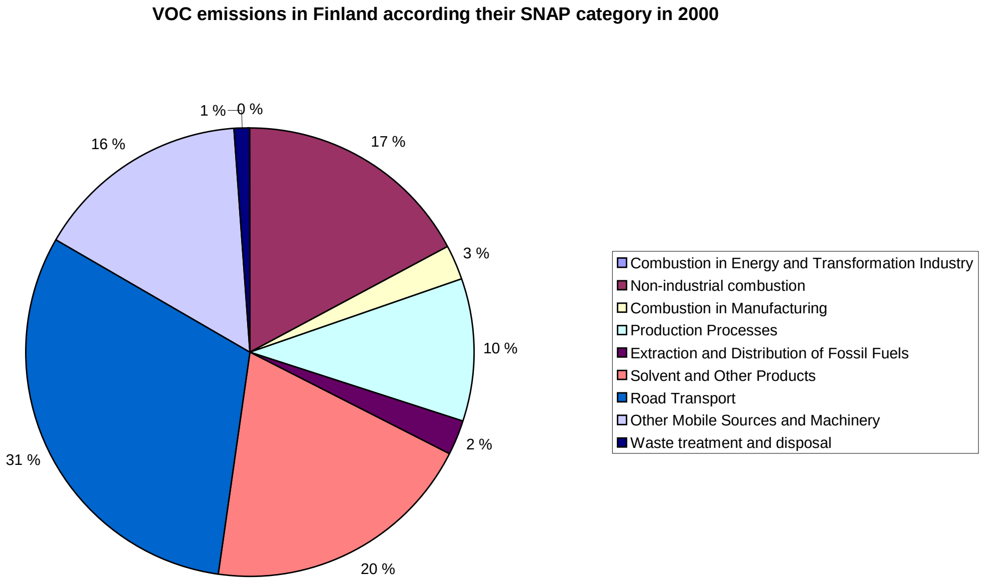

Figure 1 NMVOC emission in Finland 2000 [2]. Total emissions 161.3 kt/a.

Concern about climate change and the extinction of fossil energy resources have increased the pressure on policies for increasing renewable energy utilization. This will probably lead to increase consumption of wood and thereby lead to higher emissions of VOC if the currently operated stoves and small single-family house and residential-commercial boilers will not be replaced by more modern design facilities. Importance of technological change is especially relevant in Nordic countries, where forest resources are abundant and wood is the most important indigenous fuel-based energy source.

VOC EMISSIONS FROM DOMESTIC COMBUSTION

Residential wood combustion takes place in different kinds of stoves, ovens, fireplaces and small boilers. The most of these appliances are combustion technically simple and possibilities to control combustion conditions are minimal. The fuel itself, usually birch and pine logs, are often prepared by user causing non-homogeny fuel characteristics. On top of this moisture content can be relatively high because improper drying conditions. Unequal properties, poor combustion technology and too high moisture content lead to incomplete combustion and low efficiency. As the result of incomplete combustion concentration of hydrocarbons and soot is high. Low emission altitude causes environmental and health problems especially in suburban areas.

VOC emissions correlate with fine particle emissions, but fuels moisture content have a noticeable effect on the emission rates of VOCs. The high moisture wood stove tests yielded approximately 2-4 times more VOC than the next highest wood combustion test according the study made by McDonald et al. [3]. Typical moisture content of dry firewood is around 20% but surface moisture of can go up to 50% if the fuel isn’t stored in proper way [4]. Some literature sources document also differences between wood types [3], [5], but these remain minor when compared to emissions caused by technological differences between different domestic combustion appliances.

The main reason for VOC emissions from small scale combustion is that when fuel start to gasify in furnace, appliance doesn’t offer has kinetically conditions where all organic emissions could oxidize. Technical possibilities to control air inlet are very moderate. Lack of air combined to unequal temperature of furnace causes that especially during the first 6-12 minutes high CO and VOC emissions (pyrolysis of outer parts of the fuel). After that fuel’s phase change starts to decelerate because residue carbon on surface of stick of wood slows down the gasifying process in inner parts of wood [6]. During the slow pyrolysis and gasifying stages, gases have time to react with oxygen and temperature of the furnace is already high enough to speed up the process.

METHODOLOGY AND MATERIAL

Literature information on the prevalence of different wood combustion appliances was scarce and wood use volume estimates were made in a Nordic study [7]. Emission factors are based on various literature sources, which are not usually peer reviewed. Unfortunately there wasn’t much consistency on technical description on fireplace types neither on methodology of measurements. Because relatively few studies are concentrating on NMVOC emissions from small furnaces, finding scientifically consistent data is difficult.

Fireplace/boiler type is the most important thing when specifying emission factor. Usually laboratory tests are concentrating only on flue gas quality, not combustion efficiency and autonomy of used appliances. Without specified data on furnace type laboratory test results are tricky to apply into real life. But they give accurate information on differences between fuel types.

RESULTS AND DISCUSSION

Wood use quantities and VOC- emission factors were estimated for different kinds of combustion appliances, and NMVOC emissions were calculated (Table 1). Emission factors used vary between different appliances, from ≈ 0mg (NMVOC)/MJ of pellet stoves to 1272 mg (NMVOC)/MJ of conventional iron stoves.

Table 1 presents the results. If country specific information [8] was detailed enough it was primary source of emission factors, otherwise emission factors presented [9] and [10] were used.

Country	Wood use [TJ/a]	Em. factor used [mg/MJ]	Range of emission factors[2]	Emissions (tons NMVOC/a)
Conventional manually fed boilers without acc. tank	2 700	134	20-400	361
Conventional manually fed boilers with acc. tank	5 400	13	13-400	69
Pellet boilers	100	0[1]		0
Automatically fed boilers other than pellet	1 400	<12.7	<12.7-80	14
Conventional iron stoves	1 100	671	15-1600	738
Masonry heaters and stoves	8 000	520	15-1600	4 160
Masonry ovens	5 900	134	15-1600	790
Kitchen range/stoves	5 300	520	15-1600	2 756
Sauna stoves	8 600	671	15-1600	5 771
Open fireplaces	600	1272	800-1700	763
Total	**39 100**			**15 421**
Emission derived from official UNECE inventory (includes all non industrial combustion)				**27 700**

Table 1 Energy consumption, NMVOC emission factors and emissions in the residential wood combustion appliances in Finland in 2000 [8], [9], [10].

1 no data on pellet VOC emissions was available. Pellet boilers typically have lower emissions and better heat production efficiency than log boilers. Water contest is lower than logs and fuel is homogenous.

2 small emission factors include primary and secondary abatement measures.

Addition of accumulator tank on existing installation reduces around 90% of emission. By using new kind of arina technology in stoves emission reduction can be over 95% [4], but this type of installation (2 staged air input) needs also some orientation from the user side. These kinds of installations suit well for example kitchen and sauna stove type of appliances. In the future on going increase of pellet boiler installations will decrease VOC emissions, but on the most significant sectors (conventional stoves, masonry heaters and sauna stoves use of pellets is unrealistic).

It is clear that error range of emission factors is remarkable even when sub activity share is this detailed, but these inherent errors have to be tolerated.

CONCLUSIONS

By using one emission factor per fuel type country specific emissions can be easily greatly overestimated. The biggest problem for estimating national VOC emissions from residential combustion is large error range and data quality from test measurements. Because imperfect vintage data of old masonry heaters and other appliances decision of used emission factor is also troublesome. Typically installation lifetime can be easily over 25 years in Finland in the most relevant sectors (sauna stoves, masonry stoves and heaters, kitchen stoves). This means that autonomous decrease of VOC emissions is significant through improved thermal efficiency in new appliances (improved furnace and arina design, increased/standardized use of accumulators) is sure but slow.

Reducing emissions in old devices is possible in large scale through primary and secondary technical measures. Still, the most cost efficient way in devices with short autonomy time is a guidance of user in some principle things, drying of fuel, using right size of charges during the use (small ones in beginning and larger logs after furnace temperature has gone up and stabilized), controlling the air inlet during the use.

It is clear that lack of scientifically acceptable data on VOC emissions, activity data between different appliances and estimates of age structure of the appliances in this area is causing results that have large error range. In order to correct this, more field studies should be made and those studies should be published and reviewed. By concentrating the most important sub sectors (conventional stoves and masonry ovens) accuracy of emission factors in these sectors would be easy to improve and this way error range on estimation of total residential wood combustion sector would be significantly smaller.

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