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Investigation of real life operation of biomass room heating appliances – Results of a European survey

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HIGHLIGHTS

- First European wide survey about behavior of biomass room heating appliance users.
- Survey by online multi-lingual questionnaire in seven languages.
- Paper present extensive data set based on 1980 responses.
- Results show a detailed image how room heating appliances are used in real life.

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ABSTRACT

Wood combustion is the main renewable heating source for European households and responsible for a large portion of the particle matter in the atmosphere. Firewood operated small-scale residential wood combustion units such as firewood stoves and tiled stoves are the most widespread wood combustion appliances in households. Next to purely technological reasons (i.e. type and age of appliance) and installation conditions (i.e. natural draft of chimney system), user behavior which includes all influences caused by the user during operation has a considerable effect on the combustion performance of room heating appliances. User behavior includes fuel related factors, different ways to ignite the fire, combustion air settings, as well as frequency and intensity of use. The objective of this work is to investigate user behavior by means of a survey. The survey aims to provide an overview as to how room heating appliances in European countries are used in real life. We performed a 28 question, multi-lingual online survey over a 14-week period. 1980 responses from 16 European countries were received. Most respondents are from Italy (35%), Germany (34%), Austria (12%) and Sweden (11%). Results were separated by heating appliance type (firewood stove, tiled stove, cooker and other firewood stove), and by country. The results show a unique and detailed glimpse as to how room heating appliances are used in real life. They include the ignition procedure including used fire starters, point of fuel recharging, combustion air regulation and frequency of use. Results related to the fuel used (i.e. type of fuel, fuel conditions) are given in this paper, too. The results are crucial for further research and complement existing knowledge about the effects of the individual user and fuel related parameters on emissions and efficiency of room heating appliances.

1. Introduction

Wood combustion is the main renewable energy source for heating purposes in households in Europe [1]. Wood combustion provides a sustainable substitution for fossil fuels, which leads to

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a decrease in the greenhouse gas emissions [2]. However, wood smoke has become one of the major sources for particulate matter (PM) in the atmosphere [3–13]. Various studies have shown that especially particle emissions of category PM10 and PM2.5 can seriously affect public health [14–17].

The most widespread wood combustion appliances in households are firewood operated small-scale residential wood combustion (RWC) units. The majority of these units are firewood stoves, tiled stoves, open and closed fireplaces, inserts and cookers. They are mainly used as direct room heaters. The total number of these appliances is estimated to be more than 65 million in Europe [18]. Many studies have shown that the emission level of RWCs is high in comparison to other biomass combustion appliances such as boilers for firewood or wood pellets [19–22]. According to the study of Schmidl et al. [21], PM emissions of a firewood stove was ten times higher than from a wood pellet boiler. Kjällstrand and Olsson [22] pointed out that carbon monoxide emission of a wood stove was 20 times higher than of a wood boiler. These results were further corroborated by other studies [23–26].

Generally, the emissions of firewood operated room heaters depend on many factors which can be attributed to combustion technology, installation conditions, fuel quality and user behavior. Combustion in a firewood operated room heater is characterized by natural convection-driven combustion. Thus, the combustion quality is limited when compared to automatically controlled systems such as pellet boilers which offer comparatively low emissions and high efficiency [19,27–29]. The emissions of firewood operated room heaters depend on the type and age of the appliance. Evtyugina et al. [30] showed that there were higher carbon monoxide emissions when burning European beech in an open fireplace compared to a firewood stove. The main reasons were a lower combustion chamber temperature and the uncontrolled combustion air supply in the open fireplace. Kelz et al. [25] stated higher particle emissions for a modern firewood stove compared to a tiled stove. Due to technological progress in recent years, the emissions level of room heaters has been reduced considerably. The influence of the age of the appliance on gaseous and particle emissions were shown in numerous studies [16,19,20,22,23,31–33].

Beside the combustion technology, the installation conditions have an effect on emissions as well. Especially the natural draft of the installed chimney system has a considerable effect on the combustion performance of room heating appliances [34,35]. The draft is mainly affected by the construction material, diameter and length of the chimney and environmental influences (i.e. ambient pressure, wind).

Moreover, there are factors of significant influence caused directly by the user during operation of a room heater. These can be subsumed as user behavior. These include fuel related factors, the method of ignition, combustion air settings as well as frequency and intensity of use. The currently available studies about user behavior show an impact on the emissions and efficiency during operation [35–38]. Beside studies about multiple user related factors several studies investigated specific factors.

For instance, the significant influence of wood species on the combustion performance of room heaters were stated in several studies [30,33,36,39–43]. Beside the wood species, other fuel related parameters such as water content, log size and number of logs in the combustion chamber showed an effect on the combustion performance [44–46]. Additional publications show the effect of user behavior related factors on the performance of room heaters such as fuel placement, ignition point, moment of fuel refilling and damper settings [31,44,47–49].

The behavior of room heating appliance users has been investigated in very few studies. Gras [50] investigated operating parameters of room heating appliance user in Australia. The results show an overview of the typical use of room heating appliances of 1007 users which were interviewed by telephone. Todd [51] studied the way Australians use their wood heaters. In this study, 86 users answered a questionnaire about fuel related parameters and practical operation.

In Europe, two studies have been published. Schieder et al. [52] studied user behavior in Austria in two different surveys. In a short survey, 513 heating appliance owners were asked about the heat output, days of operation and the volume of burned fuel per year. In an additional survey 139 users answered an extensive questionnaire about their stove, the installation behavior and their user behavior during heating operation. Reichert et al. [35] investigated the user behavior of 108 firewood operated room heating appliance in Austria by interviews. Their questionnaire contained 15 questions which covered information regarding the appliance, fuel, and user behavior during appliance operation.

In summary the behavior of room heating appliance users in Europe is insufficiently investigated. Available studies from Australia are not directly transferable to Europe due to different appliance technologies, installation environments, building types and climate conditions. Studies from Austria are based on a limited response and, by their nature, only represent one European country. Additionally, it is difficult to compare or to summarize results of different surveys, due to different questionnaires and ways of survey execution (e.g. telephone or personal interview).

The available studies show a considerable influence of the user behavior on emissions and efficiency of room heating appliances. So far, this behavior has not yet been sufficiently investigated in Europe which could be crucial for further developments. This paper reports the results of a survey of firewood room heating appliance users in Europe.

The objective of the survey was to investigate the main relevant parameters in terms of emissions and efficiency during real life appliance operation. The results provide for the first time a unique image how room heating appliances are used in real life in European countries.

The results of the paper are relevant for researchers, decision makers in the field of air pollution control and standardization and the relevant industry.

Research about emissions reduction from wood combustion, development of advanced room heating appliances and potential of user education will benefit from this paper. Also results may contribute to emission source research.

In addition, the results can be used for the development of new type testing standards for room heaters which also take user behavior into account. The results and proximate research will support decision-makers of national and European room heating standardization and air pollution control activities.

For industry the results will help to understand the user behavior of their customers and may support the development of improved heating appliances which provide high performance and low emissions even in real life operation.

2. Material and methods

The survey was performed as an online survey. The open source online survey application LimeSurvey® was used [53].

A set of 28 questions was defined which asked for information about the heating appliance, installation conditions, user behavior and fuel used (see Appendix A). The scope of the questionnaire was defined based on a literature study and our own experiences about the user impact on the performance of wood fired room heating appliances.

The wording of the questions was designed to be easily understood by users with a non-technical background. Questionnaire