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The impact of a new emission control act on particulate matter emissions from residential wood energy use in Bavaria, Germany

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ABSTRACT

The use of wood energy for renewable heat production in private households has grown considerably in central Europe in the past years. Residential wood combustion is Janus-faced with regard to air emissions. Besides yielding lower greenhouse gas emissions than the combustion of fossil fuels, wood combustion is associated with pollutant emissions that are harmful to human health. The heating systems have great potential for emission reduction due to the widespread combustion of wood in installations that are often overage. An emission control act aimed at heating system modernisation and emission load reduction has recently taken effect in Germany. This paper analyses the development of the particulate matter emission load from wood energy combustion in the case study area of Bavaria until 2035. It also evaluates the impact of the legal amendment. The emission load of prevalent heating systems is calculated based on two wood consumption scenarios, and the influence of the emission control act is analysed, taking into account retro-fitting and the replacement rates of old heating systems. The results show that particulate matter emissions could be reduced considerably and there is potential for an increase in the efficiency of resource use in the domestic heating sector.

1. Introduction

1.1. Problem statement

The European Union has set ambitious targets for renewable energies and greenhouse gas emission (GHG) reduction. The political goals, together with rising prices for fossil fuels, have entailed an increasing demand in renewable energy. Wood combustion is Janus-faced with regard to emissions to air (Wilnhammer et al., 2015). On the one hand, the rising substitution of fossil fuels through wood energy can have positive impact on greenhouse gas emissions. However, according to Agostini et al. (2014) it is important to note that in order to assess the climate change mitigation potential of forest bioenergy pathways, the assumption of biogenic carbon neutrality is generally not valid if carbon stock changes in the forest are not accounted for. For example, Giuntoli et al. (2015) pointed at the importance of protecting long-term forest productivity for climate change mitigation and Holtsmark (2015) concluded that bioenergy from slow-growing forests usually has a larger climate impact in a 100-year timeframe than fossil oil and gas. On the other hand, there are rising concerns about harmful dust emissions, i.e. particulate matter (PM), carbon monoxide and hydrocarbons (UBA, 2007). Increasing dust emissions from wood energy use in the last years in Germany were predominantly caused by the rising combustion in residential heating systems (UBA, 2014a). PM emissions from small combustion plants have increased by more than one fifth from 2005 till 2010 (Ewens, 2014). According to research done by the World Health Organization (WHO, 2006), particulate matter emissions entail an average reduction in human life expectancy of 10 months in Germany. However, the WHO data refer to the year 2000 and since then particulate matter emissions from residential heating with solid fuels have been increasing by more than 50%, according to data by UBA (2013).

The challenge to lower emission load has been acknowledged by policy makers in a set of protocols and legal acts. For example, the Gothenburg protocol, commits European countries to reduce particulate matter emissions by 26% until 2020 in comparison to 2005 (UBA, 2013). In Germany, the Federal Emissions Control Act (BImSchV) was adopted to facilitate the implementation of the Gothenburg protocol, and to conform to the EU Ambient Air Quality

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Directive 2008/50/EC (European Commission, 2008). The act aims at reducing pollutant emissions via more efficient wood energy use in residential heating systems and sets emission limits depending on the material burnt. According to BMU (2014), the act would help to reduce nationwide emission load from small heating systems from 24,000 to 16,000 tons in 2025, and thus add to fulfilling the targets set in the Gothenburg protocol.

This paper builds on the work presented in Wilnhammer et al. (2015) but the novelty is that it introduces an analysis of the impact of the new emission control act on emission load and on resource use efficiency.

1.2. State of knowledge and need for research

Lim et al. (2012) revealed that worldwide particulate matter emissions are the main environmental root of ill health, and that air pollution causes about 7 million premature deaths per year. Kim et al. (2015) provided an overview on the adverse health effects of particulate matter emissions. Lu et al. (2015) conducted a systematic review and a meta-analysis of the adverse health effects of dust pollution in China. Song et al. (2016) reported on the health impacts of particulate matter, on increased mortality rates and on serious health threats such as respiratory diseases, cardiovascular diseases and chronic bronchitis. Pascal et al. (2014) revealed that particulate matter emissions have a significant short-term impact on mortality in France. Giuntoli et al. (2015) highlighted several environmental impacts associated with the use of wood energy, amongst them local air pollution through particulate matter emissions, and pointed out that any action promoting wood energy use should consider whether proper actions for the management of adverse effects are in place. Caserini et al. (2010) showed that emissions from domestic devices correspond to almost one third of the total particulate emissions in Italy in 2005. Lamberg (2014) compared small-scale wood pellet boiler emissions in Finland with other combustion units as well as with non-wood energy sources, and found that different biomass raw materials exhibit significant particle emissions. Nussbaumer et al. (2008) provided an overview on particulate emission factors from biomass combustion from different European countries. They found a wide range of emission factors and showed that automatic combustion plants are strongly related to particle removal, and that optimal operation is a major contributor to reduce PM emissions.

In the UK, the contribution of emissions from domestic wood combustion to total $PM_{2.5}$ has increased over recent years while overall emissions of $PM_{2.5}$ have strongly fallen in the past decades (UK National Statistics, 2015). McFiggans (2015) showed that through the governmental incentives in the UK that aim at increased heat production via biomass, -only boilers and pellet stoves could have further unwanted consequences for air quality in the future. In northern Europe residential wood combustion is relatively common and has been considered as a potential way to reduce GHG emissions (Karvosenoja et al., 2004). Molnar and Sallsten (2013) revealed that particulate matter emissions in northern Scandinavia were much higher in 2001–2010 than in 1990–2000 which might have been caused by the increased use of wood for heating in Sweden. However, air pollution and particulate matter emissions levels in Scandinavia are generally lower than in other European countries, and in recent years there has even been a slight decline in emissions e.g. in Norway (Norwegian Institute of Public Health, 2014).

In Germany, overall dust emissions from wood combustion have been increasing considerably from 20,000 tons in 2000 (UBA, 2007) to 30,000 tons in 2010 (Ewens, 2014), corresponding to an increase in the $PM_{2.5}$ fraction from 19,600 tons to 29,400 tons (EEA, 2013). Given the high amount of wood energy consumption, it is unclear whether the political targets for emission reduction can be met by 2025. Wood-fired residential heating systems contribute significantly to particulate matter emissions, especially non-automatic furnaces. About half of these systems is older than 20 years and is responsible for about two third of the total dust load (BMU, 2014). Moreover, increased resource use efficiency offers a potential for lowering greenhouse gas emissions and for increasing energy use efficiency.

The modernisation of these installations thus creates an opportunity for meeting the political targets with regard to both efficient bioenergy expansion and emissions reduction. The retrofitting of old installations also facilitates a more efficient consumption of the renewable yet limited resource wood.

However, data availability is low as regards the present amount of wood consumed per appliance. Due to recent publications by Friedrich et al. (2012) and Gaggermeier et al. (2014), data availability for the province of Bavaria is comparably high. Besides mere consumption, emission load depends on the combustion technology of installed heating systems. However, the results of residential heating system statistics vary according to different data sources and data collection methods (Joa et al., 2015). Additionally, there is a wide variety of $PM_{2.5}$ emission factors, as these are closely linked to the age of an appliance and associated technology (Kelz et al., 2012) and to the wood assortments used (Nussbaumer, 2003).

As the new emission control act sets legally binding minimum requirements regarding emission factors per installation, low-performing appliances will be forced out of the market and replaced with modern systems, or be retro-fitted with new filter technology. For reliable projections on future emission load, it is thus essential to assess the retro-fitting and decommissioning rate of existing appliances, as well as which new types of heating systems will be used and how much wood will be burnt per appliance. In light of the increase in emissions harmful to human health, there is need for research on how emission load will develop in the future and whether the targets for PM emission reduction can be achieved as a result of the introduction of the law amendment.

1.3. Objectives and research questions

The presented study aims at evaluating the impact of the law amendment on $PM_{2.5}$ emission load and at exhibiting the impact of policy measures and technological development on emission reduction against the background of increasing wood consumption and augmenting $PM_{2.5}$ emissions in the case study area Bavaria. We concentrate on the predominant use of wood for thermal energy production in private households, i.e. heat production from solid wood and pellets. The study strives to answer the following research questions:

- What is the current emission load from wood energy use for heat generation in private households, considering the specific combustion systems installed in Bavaria?
- How will PM emissions evolve until 2035, taking account of the law amendment and the replacement of old technologies?

The paper will describe the development in wood energy consumption in the study area, provide an inventory of installed heating systems, and exhibit its future development, Moreover, the impact of the law amendment on the modernisation rate of heating system stock will be analysed and conclusions will be drawn on the development of the associated $PM_{2.5}$ emission load in the study area.