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Survey of modern pellet boilers in Austria and Germany – System design and customer satisfaction of residential installations

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HIGHLIGHTS

- Legal framework conditions influence design of modern heating systems.
- Operational behavior of pellet boilers is usually better in new buildings.
- Majority of residential customers are highly satisfied with their pellet boiler.

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ABSTRACT

The variety of available technical building equipment leads to increasingly complex heating systems with various requirements for efficient operation. Furthermore, in existing buildings the heating system is often historically evolved and contains parts having different ages. Those systems have limited capacity to suit the requirements of replaced components. This paper investigates the operational behavior of small-scale pellet heating systems in Austria and Germany, considering installations in new buildings and boiler replacements in existing buildings and how they are influencing the customer satisfaction.

This investigation was carried out by means of a comprehensive survey for residential customers using pellet fired heating systems. More than 2500 questionnaires were distributed between 2011 and 2013 in Austria, Germany, Greece, Spain and the United Kingdom. In total 293 returned questionnaires were evaluated. The efficiency of the monitored heating systems was estimated using surveyed boiler parameters. Successively, the influence of different operational parameters on the boilers efficiency was evaluated with a statistical analysis, using Pearson correlation coefficient and Spearman correlation.

Results showed that the correct installation of the monitored pellet heating system is easier for new buildings compared to the replacement of old fossil boilers in existing buildings. Optimal operating conditions are characterized by less frequent ignitions and by higher operational loads. Pellet systems operated with a high efficiency in both building types, but for new buildings it is more likely to occur. More than 87% of the participating customers stated that they are highly satisfied with their pellet boiler.

1. Introduction

With the climate and energy package, the EU leaders set the reduction of greenhouse gas emissions to 20–30% below 1990 levels as one of the key objectives for 2020 for limiting global warming to 2 K [1]. Apart from reduction of final energy consumption, the increased use of renewable energy (e.g. solar, wind, water or biomass) can help to reach these goals. The usage of wood pellets for the provision of residential space heating and domestic hot water has become more popular in Europe [2]. Thus, there is a high potential for the reduction of carbon dioxide emissions from residential heating systems. There are several legal frameworks available which promote biomass heating. In Germany this is done via legal regulations and financial support. Examples for this are, among others, the funding programs from the Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und

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Nomenclature

N	number of observations (–)	t_{op}	operating hours of the boiler (h)
N_{start}	number of boiler starts (–)	$t_{op,cyc}$	runtime of the boiler per boiler start (h)
P_n	nominal capacity of the boiler (kW)	X	generic variable (–)
Q_{out}	energy output of the boiler (kJ)	Y	generic variable (–)
r	Pearson coefficient (–)	β	boiler load (%)
t_{full}	full load operating hours (h)	ρ	Spearman coefficient (–)
$t_{full,cyc}$	full load operating hours per boiler start (h start^{-1})		

Ausfuhrkontrolle, BAFA [3]) and the Reconstruction Loan Corporation (Kreditanstalt für Wiederaufbau, KfW [4]). The main objective of their programs is the promotion of modern heating systems in existing buildings, mostly by investment grants. There are several subsidies which can be granted additionally if, for example, a buffer storage with a minimum storage volume is part of the installation or if a solar thermal system is installed [5,6]. The Austrian government promotes the replacement of existing fossil-fuel boilers with renewable energy heating systems [7]. In many cases this is done without any additional requirements to the installation. Only some federal states, like Upper Austria, require additional measures like high efficient circulation pumps [8]. In the United Kingdom the promotion of biomass heating is done with the Domestic Renewable Heat Incentive (RHI) [9]. In contrast to the German schemes the RHI does not distinguish between different designs and installations. Other countries, like Greece, grant financial support for a wider range of energy efficiency measures and are not specifically promoting biomass heating [10].

The nominal efficiency of biomass fired central heating boilers has increased from the 1980s to 2010 from 55% up to 90% [11]. In the last decade, the boilers efficiencies during stationary operation at nominal loads, reached maximum values above 93% [12,13], but the typical dynamic operation restricts the significance of such stationary tests. New dynamic test methods are addressing the system as whole and allow the estimation of seasonal performances. A novel test method for pellet boilers was introduced by Heckmann et al. in 2010 [14]. Further details on the test cycles and the obtained results were given by Schwarz et al. [15] and Carlon et al. [16]. For biomass based combisystems further test cycles are available [17]. The most common method is the concise cycle test [18–21] by the Institute for Solar Technology (SPF). In contrast to fossil-fuel heating systems, like gas or oil boilers, operation of pellet boilers is more sensitive to transient operating conditions, quick load changes and frequent start–stop cycles. This behavior requires elaborate planning, dimensioning, installation and operation of biomass heating systems. Correct dimensioning of the boiler capacity is crucial for a highly efficient boiler operation. Liao and Dexter [22] showed in 2004 that the ratio of boiler capacity to buildings heating load ranges between 1.3 and more than 1.8 for 25 heating systems in the United Kingdom. The non-profit organization co2online evaluated 75 boiler replacements in Germany and showed that the fuel energy consumption changes after the boiler replacement in a range of −50% up to +10% with an average reduction of 22% [23]. They showed that the omission of a proper hydraulic balance and a suboptimal adjustment of the heating system is one of the major reasons for a disappointing boiler replacement.

Bemmann et al. [24] showed in 2006 a large potential for the optimization of combined pellet and solar systems, especially in terms of the control strategy, hydraulics and heat storage. Similar results were obtained by Schraube et al. [25] from the monitoring of nine pellet fired domestic heating systems in Germany and France. They stated that the performance of such systems is depending on different parameters, like planning and dimensioning of the system, the structure of the building and the setting of the operating parameters. Heinz et al. [19] did a field monitoring of five combined pellet and solar systems with the focus on the derivation of optimization strategies by adapting the control and the hydraulics of the systems. There are several further published measurements of monovalent or bivalent biomass heating systems [21,26–29]. Others, like Haberl et al. [20] or Haller et al. [30], focused on the optimization of combined pellet and solar systems based on simulations and/or lab tests. Studies revealing the influence of different configurations on the thermal performance of heating systems, the market structure and the most common problems in practice are quite rare. Most of the available studies only monitored a small number of heating systems [12] and were focused on the estimation of the thermal performance, the derivation of possible approaches for the optimization or the development of high efficient components and configurations.

In the light of this context, the present study focuses on the different configurations, which are applied in practice and how they influence the thermal performance of the installed pellet boiler as well as the satisfaction of the customer. The study also analyses the differences between pellet fired heating systems installed in new buildings and systems which are installed as a replacement for existing fossil heating systems. An extensive survey of residential customers in Central Europe was carried out within the European research project BioMaxEff (www.biomaxeff.eu). Additionally, continuously measured boiler data was used to determine the operational parameter with the highest informative values for the efficiency of the boiler operation. The results of the data evaluation where then applied to identify the main factors that have an influence on the design and thus also on the efficiency of such systems.

2. Methodology

This study was carried out by means of two different field measurement campaigns (see Section 2.3) and a comprehensive survey (see Section 2.1) for residential customers using pellet fired heating systems. Continuously measured data sets from eight monitoring sites were used to identify the boiler parameter with the highest statistical influence on the annual fuel utilization efficiency. This was done using Pearson product–moment correlation coefficient and the Spearman's rank correlation coefficient. These correlations were used afterwards to evaluate the survey data and characterize operational behavior of the pellet boilers.

For the survey more than 2500 questionnaires were distributed between 2011 and 2013 in Austria, Germany, Greece, Spain and the United Kingdom. In total 293 returned questionnaires were evaluated (see Section 2.2). The evaluation of the survey was mainly focused on the customer satisfaction and the design of the heating systems as well as the operational behavior of the surveyed pellet boilers.

2.1. Residential customer survey

In spring and summer 2011 the first draft of the survey was tested. Questionnaires were answered by the customers with the