The Impact of Consumption Based Billing on Residential Heating Behaviors: A Pilot Study of German Households

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***Abstract* - Heat is the largest single end-use sector, accounting for approximately one-third of final energy consumption in Germany. The European Union's targets for climate neutrality demand the decarbonization of the heating sector. This pilot study examines the relationship between heating billing methods and household heating behaviors in German residences. Through a comparative analysis of households with consumption-based versus non-consumption based billing systems, the conducted pilot study investigates differences in energy literacy, heating practices, and heating priorities. The descriptive findings from households reveal that residents with consumption based billing demonstrate higher self-reported knowledge of their heating and show stronger inclinations toward cost-saving and energy-efficient behaviors. In contrast, households with non-consumption based billing prioritize comfort oriented practices. These differences emphasize how billing methods influence heating behaviors and energy-efficiency awareness. Limited by sample size, this study provides valuable initial insights for developing targeted policies to promote sustainable heating practices and highlights the need for further research.**

***Index Terms*—Climate Policy, Heat Decarbonization, Household Heat, Energy Policy, Behavior Practices**

I. Introduction

Heat consumption in residential buildings is a significant contributor to energy use, accounting for approximately one-third of total end energy consumption in German households [1]. Within this, room heating represents the largest share, making up about 70% of the total end energy use [2]. Despite the increasing need for decarbonization, fossil fuels still account for 75% of the heat energy used in German residential buildings [3], and in the European Union (EU), fossil fuels power 84% of heating and cooling needs [4]. This heavy reliance on fossil fuels makes heat a critical factor in carbon footprints, contributing far more to emissions than electricity and other household energy services [2],[5].

In response to these challenges, the EU has introduced a directive aiming to increase the share of renewable energy sources by 1.1 percentage points annually [6]. However, achieving low-carbon room heating in residential settings remains difficult, with households struggling to transition to sustainable heating solutions. This challenge is central to meeting the EU's carbon targets for climate neutrality, making it an important area for research and policy intervention [7].

Low-carbon heating solutions can be achieved through the adoption of low-carbon technologies or through energy-efficient refurbishments that can lead to significant energy savings [8],[9]. Additionally, optimizing heating consumption through improved heating behaviour can also contribute to energy savings [8],[10],[11]. Nevertheless, the decarbonization of heating is particularly challenging due to several factors, including the long-lived infrastructure and deeply ingrained social practices that shape heating behaviour [8],[9].

Heating is an essential human need that is entangled with complex sociotechnical challenges, reflecting the intricate interplay between human requirements, technological infrastructure, and social practices [12]-[14]. These include the social aspects of households, such as income levels, the existing infrastructure networks in buildings, as well as the sales practices of installers [12]-[14]. The complexity of heating is further compounded by the interaction of these social and technical factors, which creates dependencies that limit alternative solutions. This results in what is often referred to as "path dependence" [15] and "lock-in" positions [16], where current heating practices and systems become difficult to change.

Previous research on heating energy-efficient behavior and practices has demonstrated that the adoption of energy-efficient technologies is influenced by several factors, including income, household size, ownership status of the residence, and self-reported comfort preferences [8],[17]-[20]. While the use of energy-efficient devices can contribute to more sustainable energy consumption, it does not automatically result in a reduction of heat consumption or lead directly to energy and financial savings, as rebound effects are often observed [21]. In fact, achieving significant energy savings is more strongly linked to the behaviors and practices of the household itself [20],[22], but also on the building characteristics and the household's paying method of the used heat [11],[24]. Several

studies on consumption-based cost reduction have already been conducted, particularly in the electricity sector [23]. Specifically, a certain degree of environmental awareness is required for setting energy-conscious temperature levels [20],[22]. Consequently, identifying the demographic and housing factors that prevent households from adopting energy-efficient behaviors is essential for the development of targeted policy interventions [18].

Several studies have examined heating behavior, revealing important areas for further research. Policies should focus on households that are less likely to adopt energy-efficient technologies, such as those who do not use programmable thermostats. This includes low-income households, residents of apartments or mobile homes, renters with lower education levels, and those who do not participate in utility incentives or home energy audits. [18] Additionally, [17] highlights the need for enhanced efforts to identify the social and psychological factors that drive or hinder the adoption of energy-efficient programs, moving beyond just the physical and financial aspects. Furthermore, [8] points out that heating behaviors vary across countries and cultures but also indicates the need of representativeness concerning demographic and housing related factors. A better understanding of heating energy consumption is therefore essential for developing effective policy measures aimed at energy savings [19]. To develop effective policy implications, they must be directly applicable to households and tailored to their specific needs. As such, policies should be designed with a high level of specificity to ensure their relevance and usefulness for different household types [25]-[27].

These analyses aim to offer first insights into how different factors interact and contribute to the sustainability of household heating behaviors.

The first step examines the relationship between heating practices, payment methods, and heating system knowledge. Furthermore, the perceived importance of the heating system, and consequently the priorities underlying heating decisions, is examined in relation to the role of the payment method.

II. METHODOLOGY

In literature and based on our survey data and results, several key dimensions are identified as essential in shaping and describing household heating behaviors [28]-[31],[33]. These dimensions, along with demographics and housing factors, serve as the foundation for analyzing heat consumption and include Energy Literacy and Knowledge, Heating Practices and Heating Priorities [28]-[31],[33].

A. Energy Literacy and Knowledge

Energy literacy plays a vital role in shaping household heating behaviours and encompasses the reported knowledge individuals have regarding their heating systems and their perceived level of control over these systems [33]. Understanding energy literacy is essential because it provides a framework to assess how individuals' behaviour aligns with their knowledge and awareness of energy usage [28]. This dimension explains variations in heating practices, as individuals with higher energy literacy are more likely to make informed decisions about energy consumption, while those with lower literacy may engage less in energy-efficient practices. Energy literacy plays a key role in predicting and explaining energy-related behaviors, influencing how people interact with heating systems. It is essential to incorporate energy literacy into policy and behavioral analysis to shape attitudes toward energy use and foster more sustainable behaviors. Knowledge, as a key element of literacy, enables individuals to make more rational decisions about their heating practices and energy consumption [28]. As such, energy literacy should always be considered when addressing household energy behaviours to ensure that interventions are appropriately tailored to individuals' levels of knowledge and control [8],[27],[28].

B. Heating Practices

Existing literature identifies various heating practices, which can be categorized based on their underlying motivations and the habits related to the use of heating systems [29]. Some practices prioritize comfort, such as "heating all year", "heating all day in winter" or "wearing summer clothes in winter" [33], [29]. Others are more financially driven, including "heating all rooms equally" or "different temperatures per room" [33, 29]. Certain practices focus on building protection, such as "heating to protect the building" [33], [29], while social aspects influence behaviors like "heating for pets" or "heating for health" [33],[29]. Additionally, the perceived significance of heating systems can be reflected in practices like considering heating as "the most important energy supply in the household" [33],[29].

C. Heating Priorities

Furthermore, considering users' heating priorities is essential for the success of energy transition strategies, as policies and frameworks must align with individual values and needs to effectively encourage participation, promote long-term behavioral change, and facilitate the adoption of energy-efficient technologies and practices [30],[31]. Understanding these priorities helps establish the right incentives and guide behaviors toward more sustainable heating practices [31]. Existing literature identifies various heating priorities, which can be categorized based on their underlying motivations [30],[31],[33]. Financially driven priorities of heating include "saving money" or "saving energy" while comfort related priorities focus on "ensuring comfort", "improving quality of life" or "making daily life easier." Environmentally motivated priorities, such as "saving energy" or "environmental protection" highlight sustainability concerns. Additionally, external priorities related to the building itself include "increasing supply security" or "enhancing property value". Socially driven priorities, influenced by family members or guests, include "providing protection and care" "enhancing leisure time" or "saving time" [30],[31],[33]. Recognizing these diverse priorities is crucial for designing targeted interventions that encourage energy-efficient behaviors.

D. Materials and Methods

The disparities in sustainable and unsustainable heating practices among a sample of German residents are highlighted in this pilot study, providing an initial indicator for

understanding of how demographic and housing factors influence this residential heating behaviors and priorities.

The survey was designed to take approximately 20 minutes to complete and consisted of a series of questions divided into four sections.
The first section explored the socioeconomic and demographic attributes of the respondents. The second section examined the participants' heating knowledge and control systems. The third section investigated both sustainable and unsustainable heating practices. The fourth section focused on the heating intentions of the participants, including their heating priorities. Most questions were answered using a 5-point Likert scale (1: strongly disagree, 5: strongly agree), with a final open-ended question allowing respondents to discuss further barriers and intentions regarding their heating practices. The survey was conducted in German and administered online. The final dataset was derived through a quality check, which excluded incomplete or inconsistent responses.

In the following, Section 3 outlines the research design, the survey instrument, and the data analysis techniques used in this pilot study. Followed by the results, which are organized thematically around three key issues: Literacy, Heating Practices, and Heating Priorities.

III. RESULTS

A. Data

Initially, 46 responses were collected, but after applying quality control measures, the final sample consisted of 18 fully completed household surveys across Germany. To capture household heating intentions and behaviours in an optimal seasonal context, the survey was conducted in December 2024, during the winter months. The average age of respondents was 35.8 years. Regarding housing tenure, one-third of the participants owned their apartments, while the remaining two-thirds were tenants (see Figure 1).

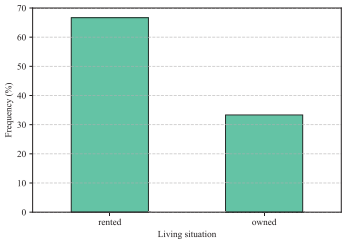

Figure 1: living situation across the households

In terms of heating cost allocation, 56% of the surveyed households reported using a 100% consumption based billing system, whereas 44% paid based on a non-consumption based model. In terms of heating cost allocation, 56% of the surveyed households reported using a 100% consumption based billing system. In this billing method, heating costs are calculated based entirely on the actual heat energy consumed by each individual household. The remaining 44% paid based on a non-consumption based model. Under this non-consumption based approach, households pay a fixed amount, with no direct accounting for actual energy consumption. Additionally, 11.1% of respondents indicated that their rented apartments had undergone energy-efficient refurbishments, while 88.9% reported no such improvements. The survey also examined the age of residential buildings. A total of 16.7% of residents lived in buildings constructed before the introduction of Germany's first building energy efficiency regulations in 1952 [34], while 11.1% resided in buildings constructed between 1952 and 1977. In contrast, 44.5% of participants reported living in buildings constructed after the implementation of the German Thermal Insulation Regulation (1995) [35], while 27.8% were uncertain about their building's construction period. The income distribution in the sample is spread across all income classes and is depicted in Figure 2.

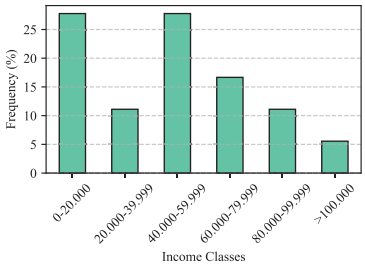

Figure 2: income classes across the households

Most respondents lived in two-person households. Regarding time spent away from home, one-third of participants reported being absent for a maximum of 30 hours per week, while 22.2% were away for 51-60 hours weekly. Concerning heating systems, the majority of households used radiators, with only one respondent reporting the use of an underfloor heating system.

B. Energy Literacy and Knowledge

The following section presents the self-reported knowledge and control over heating practices in households based on payment methods. As illustrated in Figure 3, households with a 100% consumption based billing method reported a higher

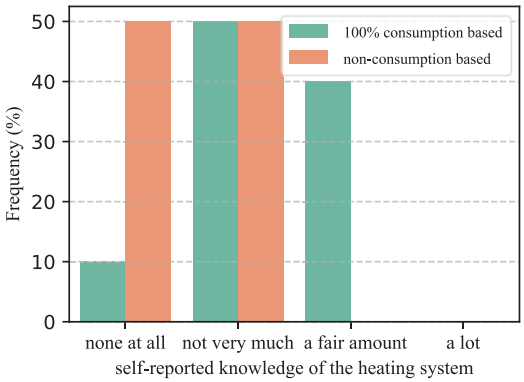

Figure 3: self-reported knowledge of the heating system by payment method

level of knowledge compared to those using a non-consumption based payment method.

While non-consumption based households predominantly reported "none at all" or "not very much," 90% of households with a 100% consumption based billing method stated that they knew "not very much" or "a fair amount" about their heating system.

Figure 4 illustrates the self-reported control over the heating system based on payment method. Residents with a non-consumption based payment method reported a lower level of control over their heating system compared to those with a 100% consumption based billing method. The highest reported level on the 4-point Likert scale for households with a non-consumption based payment method was 3 ("a fair amount"), whereas, in comparison, households with a 100% consumption based billing method reported the highest level, "a lot."

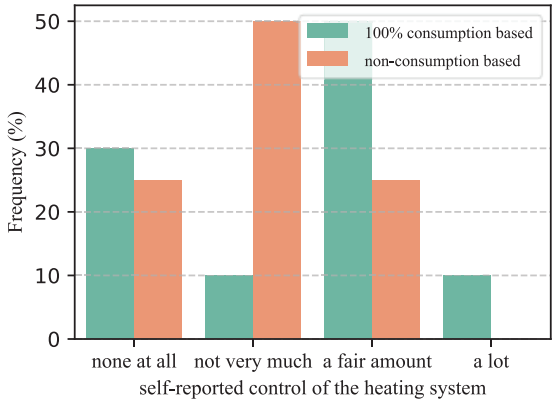

Figure 4: self-reported control of the heating system by payment method

C. Heating Practices

Figure 5 illustrates the differences in heating practices based on payment methods. The highest reported and relatively similar necessities in heating practices is observed in *"Opening windows in winter"* and *"Setting different temperatures per room*", across both payment methods. While most heating practices show notable variations, such as "*Heating is the most important energy service*", "*Heating all rooms equally*" and "*Wearing summer clothes in winter*" the heating practice "*Heating is the most important energy service*" is reported as a necessity by 80% of households with a 100% consumption based payment method, compared to only 55% in households with a non-consumption based payment method. The heating practices "*Heating all rooms equally*" and "*Heating to protect the building*" are shown Figure 5 to have a higher reported necessity in the group of 100% consumption based households. In contrast, households with a non-consumption based payment method reported a higher necessity for the heating practices "*Heating for health*", "*Heating for pets*" and "*Heating all day in winter*". The heating practice "*Heating all year*" is reported with a relatively low necessity in both payment groups, with 25% in the non-consumption based and 26% in the 100% consumption based group.

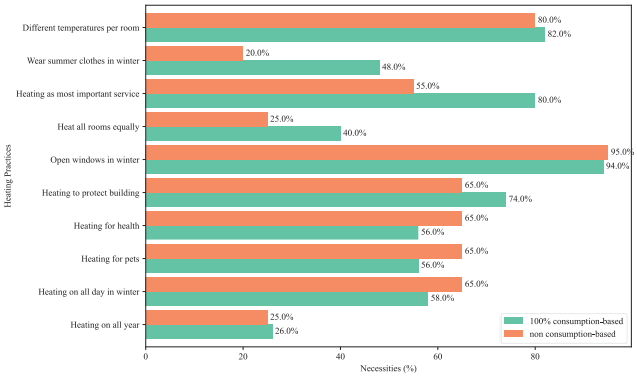

Figure 5: key heating practices

D. Heating Priorities

Figure 6 illustrates heating priorities among households with different payment methods. *"Environmental protection"* is the highest and most reported heating priority, while *"Enriching leisure time"* is the least reported. The largest differences are observed in *"Increasing property value", "Saving energy"* and *"Saving money"*. Households that pay based on 100% consumption, in addition to prioritizing *"Environmental protection",* report *"Saving money"* as a key priority. In contrast, households with non-consumption based payment methods prioritize *"Improving quality of life"* the most in addition to *"Environmental protection"*. Similar heating priorities in both payment groups, in addition to "*Environmental protection*" include "*Increasing supply security*", "*Improving quality of life*", "*Enriching leisure time*" and "*Enriching comfort*". For the heating priorities "*Ensuring comfort*" and "*Saving money*" Figure 6 shows that non-consumption based households report a slightly higher necessity for "*Ensuring comfort*" (65%) compared to "*Saving money*" (60%) or "*Save Energy*" (65%). However, in the 100% consumption based households, a stronger difference is observed, with 84% reporting "*Saving money*" as a necessity or 89% in "*Save Energy*", compared to 60% for "*Ensuring comfort*".

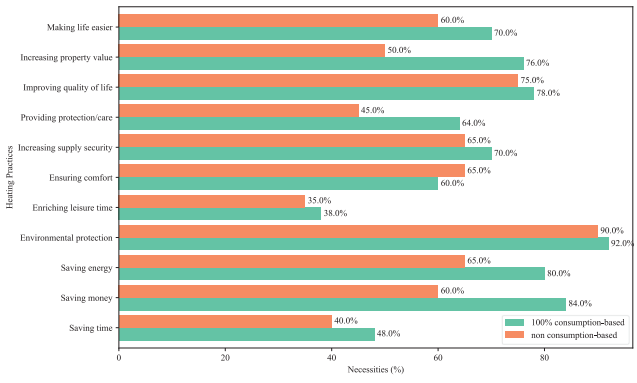

Figure 6: key heating priorities

IV. Discussion

The results of this survey among German households confirm the existence of different preferences in heating practices and priorities. These findings provide initial insights into key factors influencing heating behavior. However, given the small sample size of 18 households, the results should be considered preliminary and indicative, serving as a foundation for a larger scale follow-up study. A power analyses shows that at least a survey with 120 households is needed [37].

The descriptive analysis suggests that differences in payment methods for heating are linked to variations in self-reported knowledge and control over heating systems this in in line with findings from previous research [9].

Regarding social practices, "heating for pets" and "heating for health" are reported as having higher necessities in the non-consumption based household group, as well as the priority "ensuring leisure time." Added to that, comfort practices, such as "heating all day in winter," in combination with comfort priorities like "ensuring comfort" or "improving quality of life," show a higher-rated necessity. In contrast, the household group with a 100% consumption based payment method shows higher ratings in the financial aspects, such as the heating priorities "saving money" and "saving energy," or in the practices "heating all rooms differently." Furthermore, environmental aspects appear to be prioritized more in the 100% consumption based household group, as evidenced by higher ratings in heating practices like "heating is the most important energy service," as well as "saving energy" and "environmental protection".

The differences underline that in a larger-scale follow-up study, including payment terms for heating, it will be essential to examine the impact of various billing methods on heating behaviors, energy efficiency awareness, and the adoption of sustainable practices. This could provide more nuanced insights into how payment structures influence decision-making and environmental considerations within households.

In Section 3, Energy literacy and knowledge, it was shown that self-reported control and knowledge are lower in the group with a non-consumption based billing method. This suggests that households not paying based on consumption may engage less with heating practices, making them less likely to implement actions aligned with environmental sensitivity and climate neutrality goals. The resulting preferences of households in relation to comfort, environmental, or financial aspects across specific household groups should be validated in future research with representative samples. This could provide the basis for efficient incentives or awareness campaigns.

Additionally, it should be considered that households living in owner-occupied homes are more likely to have higher literacy levels compared to renters [8]. Therefore, this distinction should also be included in further analyses. According to studies [19-20], household income emerges as a critical factor in understanding energy consumption patterns and demographic variations. This pilot study did not include income as a factor due to its broad distribution and the small sample size (Figure 2).

It is also surprising that households consider it 20–48% necessity (Figure 6) to wear summer clothes in winter. The wide variety of heating literacy, practices, and priorities underscores the need for targeted incentives tailored to specific household groups, which can help promote more sustainable heating behaviors and enhance overall energy efficiency. Additionally, the reported necessities in heating practices provide valuable insights into broader patterns that warrant further exploration and more concrete implications.

Overall, this analysis confirms that the influence of demographic and household factors is significant, but also complex. This study serves as a foundational step for identifying areas that require deeper investigation, which could be addressed in a follow-up study involving a larger sample size. In such a study, methodologically robust tests of significant correlations should be conducted, and techniques such as logit regression could be utilized to examine discrete choice behavior and the underlying factors influencing heating practices.

V. Conclusion

This pilot study provides critical insights into the complex relationship between heating billing methods and household energy behaviors in German residential settings. The research reveals variations in energy literacy and knowledge, heating practices, and priorities across different billing approaches, demonstrating the nuanced interactions between payment structures and energy consumption patterns. While the small sample size of 18 households limits broad generalizability, the findings highlight important differences between consumption-based and non-consumption-based billing methods, with consumption-based households showing higher self-reported knowledge of heating systems and greater emphasis on financial and environmental priorities. In contrast, non-consumption-based billing households tend to prioritize comfort and social aspects of heating. These observations underscore the need for targeted policy interventions and awareness campaigns that consider the diverse motivational factors and energy literacy levels across different household types. Future research should expand on these preliminary findings through larger-scale studies, incorporating more comprehensive demographic analysis and advanced statistical techniques to develop more strategies for promoting sustainable heating practices and supporting the broader goals of energy efficiency and climate neutrality.

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