

Energy justice in heat metering

Findings from a Danish experiment of metering and distribution in residential apartment buildings

Gram-Hanssen, Kirsten; Bonderup, Sirid; Aagaard, Line Kryger; Askholm, Anne Sofie Møller

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Original research article

Energy justice in heat metering: Findings from a Danish experiment of metering and distribution in residential apartment buildings[☆]Kirsten Gram-Hanssen^{*}, Sirid Bonderup, Line Kryger Aagaard, Anne Sofie Møller Askholm*Department of the Built Environment, Aalborg University Copenhagen, Denmark*

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ABSTRACT

According to EU regulations on heat metering, households should be metered individually and pay accordingly. However, in apartment blocks, heating is often provided for the whole building, and different ways of distributing costs are used. In Denmark, an investigation has been carried out into new ways of distributing costs, using indoor climate measurements of temperature, CO₂ and humidity. Incorporating these three types of measurements in payment distribution can create an incentive to encourage residents to pursue a healthier indoor climate with lower energy consumption. This paper reports on qualitative interviews with residents as well as housing staff taking part in the experiment, relating empirical findings to questions of justice and ethics raised in the literature. Analysis reveals differing levels of understanding among residents concerning metering systems and rationales, including in relation to cost distribution and questions of justice. The experiment was carried out in social housing blocks where some residents could be categorised as vulnerable in terms of limited income and specific heating needs. Furthermore, issues of global climate and justice from an intergenerational perspective are also considered. This paper therefore draws on wider discussions about energy justice and vulnerability related to types of heat metering, and shows how these issues are interlinked with the socio-material context and the interplay with socio-technical constructions of comfort norms. The relevance of country-specific insights are thus demonstrated at a European level and beyond.

1. Introduction

According to EU directives, individual heat accounting should be in place for all units in multi-apartment buildings to give customers information about their individual energy consumption and bills in order to promote energy efficiency and reduce energy consumption [1]. Especially in existing multi-apartment buildings supplied by shared central heating, individual heat accounting may pose challenges due to technical and financial constraints related to the installation of direct metering. Therefore, the directive also includes the possibility of using individual heat cost allocation through meters that can be installed on radiators. Individual metering in multi-apartment buildings can thus be provided by direct heat metering in each apartment, or for instance by sensors for radiators distributing the heat within the building. According to a review study, these EU directives have been implemented differently in the different member states, though the use of indirect accounting schemes, using heating sensors for radiators, is the most

widespread model due to the lower cost of installation in existing buildings [2].

When heating costs are distributed among individual consumers in multi-apartment buildings, several issues should be taken into account, and Canale et al. [2] highlight three important factors. First is the fact that some apartments have a more exposed location in terms of heat loss (if the apartments are at the top, bottom or corners of the building). Second is that neighbouring apartments may gain or provide heat for each other through the walls if there are differences in temperatures between the apartments. Third is the issue of energy poverty, which implies that some households may not heat their apartment adequately, resulting in an unhealthy indoor climate for both residents and the building due to dampness and mould. These aspects are also highly dependent on the technical properties and energy efficiency of the building. To make up for the exposed location, allocation of costs according to radiator sensors may take into account different compensation strategies, balancing the variable (metered) costs and the fixed price

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^{*} Corresponding author.

E-mail addresses: kgh@build.aau.dk (K. Gram-Hanssen), sbon@build.aau.dk (S. Bonderup), lkaa@sbi.aau.dk (L.K. Aagaard), asma@build.aau.dk (A.S.M. Askholm).

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of running the system. The EU member states have different regulations in place regarding compensation as well as the distribution of fixed costs [2].

Furthermore, a problem in the green transitions related specifically to rental apartment housing blocks is the so-called split incentive [3], where landlords make the investments for energy retrofitting whereas tenants are expected to gain from it by lower energy expenditures, and thus an increased rent is often seen. However, if energy reductions are not actually achieved due to e.g. rebound effects [4], tenants may not realise these lower expenditures for heating but just increased rent. This problem is especially debated in Germany that has a high share of rental housing, and the idea of a so-called ‘partial warm rent’ has been proposed to deal with this [5]. The idea of partial warm rent is that the landlord provides a basic heat supply and that any additional consumption, meaning higher temperatures, are paid by the tenants. Possible benefits of partial warm rent have been investigated and the results point towards that alternative ways of paying for heating can incentivise landlords to retrofit, though more research is needed [6,7].

With this short introduction to heat accounting, several issues related to energy justice are in focus. Energy justice concerns the distribution of benefits and overall costs of energy production and consumption, and existing research has focused on questions of distribution, procedure and recognition [8,9]. This paper primarily focuses on the consumption aspect of the justice discussion, specifically in relation to heat accounting, a fair distribution of costs and how issues of unhealthy indoor climate can be incorporated. By using the vocabulary of energy justice, the following questions arise: what is a just distribution of the heating costs, who should decide this, and what requirements, knowledge and competences should be considered in these procedures? It is worth noting that energy justice is always related to the wider energy system, including how energy is provided and its global and intergenerational implications, since energy consumed today in the Global North will have severe consequences for the Global South and future generations [10,11].

In Denmark, an experiment has been developed to test a new way of distributing heating costs in multi-apartment buildings, notably in social housing associations [13]. The approach includes detailed indoor climate measurements of temperature, CO₂ and humidity, with a frequency of 5 min. The data are sent to a cloud computing system, which is then used for heating cost allocation and to give feedback to customers and facility staff. Proponents of this method of distributing heating costs argue that it should be a fairer distribution in terms of issues related to the exposed location of some apartments, heat loss from one apartment to neighbouring apartments, and unhealthy indoor climates. The experiment and its principles will be described in more detail below.

The approach to individual accounting presented in the EU directives [1] reflects ideas of energy justice where on the one hand, energy efficiency and savings are sought by means of energy pricing, and on the other, the distribution of costs should rely on transparent and fair principles of paying for your own consumption. In practice, however, new issues of energy justice emerge when considering how to implement the individual payments. These relate to the reliability of and trust in the metering system and related technologies, and to competences and understandings of these. In this paper, we discuss energy justice and ethical considerations related to the new systems of accounting using digital measuring of the indoor climate. We will do so based on qualitative interviews with residents and facility staff who were part of the aforementioned experiment. The aim of this paper is not to evaluate which accounting system is most fair, but rather to use the case for a detailed investigation of energy justice in the specific and local context of a housing organisation in Denmark, with the following three research questions:

- How can the right to a comfortable and healthy indoor climate be balanced with need to save energy for the sake of the global climate?

- Which socio-technical parameters influence how this question can be answered?
- Who and what should be included in the justice arguments and decisions?

As this study is based on a single housing organisation in one country, it can provide great detail when trying to understand the importance of the local context and can contribute new insights, linking energy justice to the issues of allocation of heat expenditure. To broaden the relevance to a wider international context, analysis and discussion of the results includes the perspective of European level policy and housing context.

In the following, we will first introduce some of the literature on energy justice, then based on this, we will summarise a framework related specifically to discussing issues of heating accounting schemes. The next section will then describe in detail the specific case of the new accounting scheme based on indoor climate metering, as well as our methods of data collection related to this case. The analysis of qualitative interviews will be structured according to the framework of justice developed in the following section and will focus on answering our three research questions. Finally, the discussion and conclusion will summarise our findings and their value from a policy perspective.

2. Energy justice related to schemes for heating accounting

Several studies have reviewed and summarised existing literature on energy justice, e.g. [8,14,15]. This paper does not intend to perform a literature review but will rather build on existing reviews to draw some approaches to be used in our analysis. Energy justice was first discussed in the 2010s and the concept emerges from concepts of climate and environmental justice, which in turn can be traced back to the US civil rights movement [14]. Most of the literature points to three pillars of energy justice, namely distributional, procedural and recognition justice, relating to how costs and benefits should be distributed among groups, how decisions should be made and who should be considered in this. This can also be combined with other ethical approaches to energy and be reformulated into sets of guidelines for energy policy, including that everyone should have access to and be able to afford the energy they need, and that this is based on good governance and due processes and includes an intra- and intergenerational perspective of leaving the world habitable for future generations [11]. However, these guidelines include some possible controversies. If people in the Western world consume the energy, they think they need, this may not be sustainable from a global and intergenerational perspective. Questions of sufficiency and how to live well within certain limits have been researched in recent years, also in relation to heating homes, where some have focused on the issues of increasing living space [12] and others on challenging the high indoor temperatures [16]. These discussions raise the question of how to objectively define what is ‘needed’? When it comes to heat and comfort, we know from previous research that norms of comfort (e.g. indoor temperatures) are socio-technically constructed [17–19], and achieving a sustainable future is also about questioning these norms. If we cannot objectively establish a minimum standard for what everyone should be able to afford, then how can we include a right to affordable energy? One approach to establishing minimum levels of energy services can be based on deliberative workshops, where members of the public are asked to discuss and define such minimum standards of living within different areas related to energy consumption [20]. This study reveals how minimum standards tend to develop over time and vary among different social groups. For example, access to internet and communication technology is seen as a necessity today, while only a few years ago it was seen as a luxury. Furthermore, these deliberative workshops showed that different age groups view minimum standards of indoor temperatures differently, as old people are thought to need higher temperatures than younger people [20].

Following this idea that minimum standards can be defined in

democratic processes rather than objective standards, questions of what is just and unjust can be based on different types of philosophical arguments. Galvin describes two opposing philosophical positions [14]. Where a rational metaphysical perspective implies that moral claims exist in themselves and can be explored by rational thinking, the pragmatic view say that moral claims are nothing but expressions of feelings and wants. In a rational approach, we can thus establish what is right and wrong according to ethical and just issues related to heating accounts, whereas in the pragmatic view, each argument is as valid as its opposition.

Galvin, however, also argues for a third way, building on Wittgenstein's linguistic philosophy, seeing language games as social practices. In simple terms, this approach would argue that we can talk about, and reach agreement on, what is right and wrong, because we are communities of people sharing culture, language, and practices. When following this line, however, arguments in themselves, whether based on rational metaphysical philosophy or other arguments, do not imply in any way that justice will be implemented. What is implemented is always part of a political process, but moral and ethical statements can be incorporated into this process. In relation to our case, this would imply that we *can* have a meaningful discussion on these issues, but in the end, power and politics will be what counts when it comes to making decisions about the accounting scheme.

Relating these discussions and the three pillars to the question of accounting of heating in a Danish social housing block highlights issues of ethical balancing between the heating needs of the residents versus the climate justice of reducing energy consumption, as well as justice related to who should decide the type of accounting schemes used. To delve further into these discussions, and to understand the socio-materiality of this specific case, the following will present the concept of "dynamic accounting of heating", and at the same time relate it to the energy justice discussions presented above.

3. Dynamic accounting of heating as a fairer system?

The concept of "dynamic accounting of heating" was developed by a small Danish company, who approached social housing organisations to argue its merits as an alternative to methods based on radiator sensors. The housing organisations were interested in the new concept based on its promises of a fairer distribution of heat expenditure combined with the notion of giving residents economic incentives to maintain a healthy indoor climate and thereby avoid unnecessary wear and tear on the buildings. As accounting of heating is regulated according to Danish law [21], a housing organisation must have a legal exemption to be able to experiment with other ways of accounting, and this was granted by the Danish housing minister, on the assurance that the experiment would be evaluated [22]. The following will describe the ideas and promises behind the system in relation to the justice perspective presented above.

The promise of dynamic accounting of heating is that it is fairer compared to radiator-based sensors because occupants pay according to the temperature in their rooms, regardless of whether that comes from their neighbours or from the radiator, and the cost is thus also independent of whether their apartment is in a cold corner of the building or surrounded by warm neighbours. Furthermore, it should encourage people not to keep the temperature too low and with little ventilation to keep their energy bills low. Many Danish social housing buildings have severe problems with mould due to a combination of building issues, thermal bridging, too much moisture from residents' activities, insufficient ventilation, and low indoor temperatures. Mould represents a health problem for residents and thus relates to questions of justice, as well as constituting an economic expenditure for the housing organisation in terms of renovations, thus also implying higher rents and another issue of justice.

Dynamic accounting of heating includes digital indoor climate measurement of temperature, humidity and CO₂ concentration in five-minute intervals for each apartment [13]. Rather than just paying for

heat consumption as with a radiator-sensor-based system, the idea behind dynamic accounting of heating is that the lowest cost will be associated with staying within some predefined intervals for all three measurements, corresponding to having a healthy indoor climate and a decent temperature. Specifically, this implies that someone must define the limits of what can be considered a healthy indoor climate in terms of humidity and CO₂ emissions and what can be considered a decent temperature. Specific details of the limits used in the present project can be found in [13], while Table 1 gives a summary of some of these limits based on the winter season. The low humidity limits are included to prevent over-ventilation combined with high levels of heating during the winter.

Ideally, this payment scheme could motivate residents to maintain an indoor climate that balances health and environment in a fair way by not having too high a temperature and ventilation rate, which is bad for energy consumption and thus the global climate, nor too low a temperature and too little ventilation, which is bad for the buildings and for the residents' health. It is worth noting how the issues of mould and cold are framed differently in different countries. In Denmark, there has been little political focus on energy poverty, whereas there has been a strong focus on preventing mould in residential buildings, with particular attention paid to ventilation, while other countries such as UK have framed the same issues as underheating due to energy poverty [23].

The first question of justice is who should decide the limits of 'healthy' and 'decent'? Furthermore, to work as an economic incentive in balancing the indoor climate, occupants must know when their households are above/below or within the limits. Therefore, it is important for them to receive feedback on their time-based detailed indoor measurements in order for them to learn and adjust. However, this may also raise new questions of ethics and justice, including defining who is capable of understanding and thus benefitting from the system, as well as ethical considerations in data handling when somewhat pervasive and detailed data are harvested [24–26]. Finally, there are some basic questions related to price and justice, including whether it is fairer to pay for your own consumption, or if those who can afford to should pay, while everyone should have what they need. Following EU regulation, all households should have information and individual billing of their own energy consumption [1]. The rationale behind this is to promote energy efficiency and reduce energy consumption. Thus, price can be seen as a tool for practice change. To what extent price works as a tool in this specific setup of indoor measurements is an empirical question relating to how people understand and are interested (or otherwise) in the feedback they receive, and if they have the means to react to this information.

In this experiment, the residents received feedback in the form of a two-page report distributed monthly to each household, with colours (green, yellow and red) indicating the extent to which they had stayed within the limits mentioned in Table 1 for temperature, humidity and CO₂ concentration over the past month. The meter in the households did not have a display and could not provide feedback. Initially, it was intended that this information would also be available online for staff and residents, however, this was not achieved during the project period. For residents who are not familiar with digital solutions, the paper-based

Table 1

Examples of specifications of limits for indoor climate measures used for calculating heating cost distribution.

	Good – basic payment	Less good – additional payment	Poor – higher additional payment
Temperature, °C	18–21	16–18 and 21–23	<16 and >23
Humidity, %RH	30–50	20–30 and 50–60	<20 and >60
CO ₂ concentration, ppm	<800	800–1000	>1000

version may also have been preferable. An example of the monthly printed report is shown in Fig. 1. These reports were the only feedback that residents received during the experiment, though staff were available to help them interpret the reports, as will be discussed later.

4. Case description and data collection

Three different residential areas (containing 80 to 500 apartments) within a Danish social housing association participated in the project testing dynamic accounting of heating. In Denmark, social housing consists of a number of independent non-profit social housing associations, each comprising several residential areas (called a “boligafdeling”, which translates to “housing department”). Each housing department has a board consisting of residents, and most decisions regarding the housing department must be accepted by the annual general assembly of residents, according to Danish law [27]. This process is termed “resident democracy” and is considered a pillar of Danish social housing. As well as resident democracy, the social housing sector is also heavily regulated since the building of social housing is financed by favourable state loans. Everyone can apply for social housing, although some housing departments have long waiting lists. The municipality is allowed assignment rights to 25 % of the social housing dwellings for people in need. The housing associations provide the housing departments with administrative services and are responsible for operation and maintenance, as specified by the resident democracy and the legislative requirements.

The three housing departments participating in this project were located in the regions of Jutland, Funen and Zealand. The dynamic accounting of heating was initiated after the three departments had

undergone extensive renovations:

- The Jutland housing department was located in a town with approximately 20,000 inhabitants. Apartment blocks were built in the late 1960s. The department participated with 84 apartments (of 2–5 rooms). The renovation consisted of new roofs, new windows, new balconies, a new ventilation system and new kitchens and bathrooms.
- The Funen housing department was located in a town with just under 30,000 inhabitants. Two neighbouring departments participated with approx. 250 apartments each (of 1–5 rooms), distributed across 10–12 blocks. One department was built in the 1960s and one in the 1970s–80s. The renovation consisted of creating larger apartments and disability-accessible apartments, new roofs, new doors and windows, a new ventilation system and new kitchens and bathrooms.
- The Zealand housing department was located in the urban capital region and participated with around 200 apartments (of 2–4 rooms) in one large block built in the 1970s–80s. The renovation consisted of new windows and doors, a new façade and balconies, additional insulation and modernised bathrooms.

In order to evaluate the dynamic accounting of heating project, interviews were conducted with operations or maintenance staff from each housing department, resulting in a total of five participants (referred to as staff informants in the analysis), and with residents from the Jutland and Funen housing departments, providing another 13 participants (given pseudonyms in the analysis). Staff who had been most involved in the process of implementing the new scheme were selected for interviews. Residents were chosen based on the information

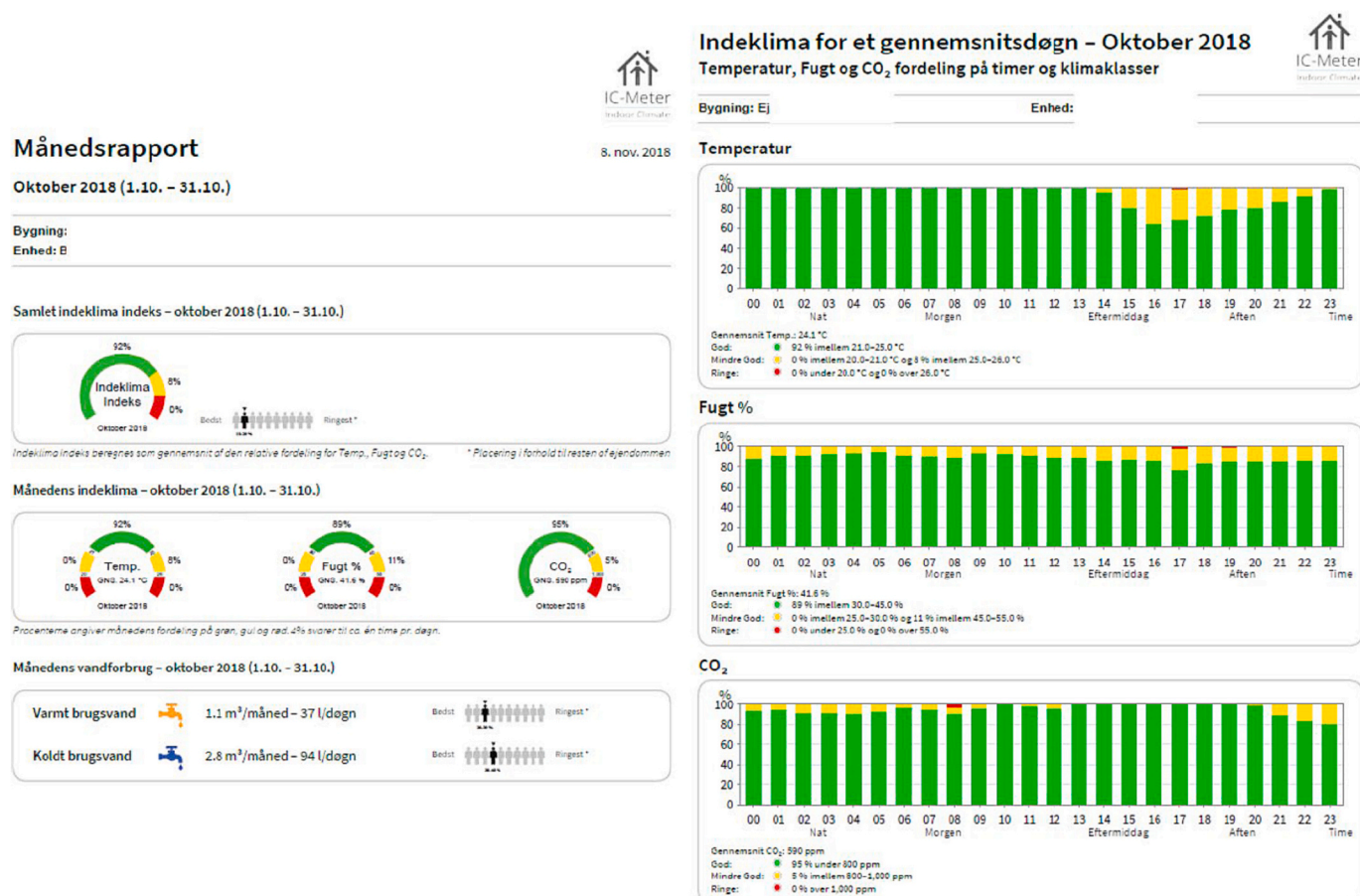


Fig. 1. An example of the report (two pages) distributed to residents on a monthly basis, indicating when the three parameters temperature (“Temperatur”), humidity (“Fugt”) and CO₂ emissions were within or beyond the limits related to the level of payment.

in their indoor metering data as well as their willingness to take part in the interview. We aimed to have variation among residents in relation to their indoor measurements and to include those who stayed within the payment limits as well as those who did not. Our selection criteria also resulted in a variation in relation to the age and occupation of informants, although it is important to note that these apartments did not accommodate higher middle class or more wealthy individuals. The interviews took place after approximately one year of the new heat accounting scheme being implemented and the completion of the building renovations, and focused on how staff and residents perceived and understood the project and how it affected their everyday practices. These interviews form the empirical material for this paper alongside the quantitative evaluation [28], documents pertaining to the project and the following debate – including websites describing and debating ideas of the accounting systems.

The staff interviews consisted of three qualitative semi-structured interviews with one or two staff members. Two were held in person and one was held via an online communication platform. The interviews lasted approximately 1 h each. Interview guides for staff included questions relating to their views on the process of introducing the new accounting scheme, the technology used, their work advising and supporting residents, as well as their overall assessment of the scheme. The 13 interviews with residents were mostly telephone interviews due to COVID-19 restrictions, but one was held in person. They lasted between 20 min and 1½ hours, and the interview guide included questions on their experience of the implementation process of the new scheme, their understanding of it, as well as the extent to which it had affected their heating and ventilation practices. All interviews were audio recorded and transcribed. Interview guides and selection criteria are further described in the report [29]. The empirical study followed the ethical standard of our university, including European GDPR rules [30] on data protection. All quotes were translated into English by the authors, and when using pseudonyms for the residents, we add F or M to indicate female or male respondents. All staff informants were male.

5. Analyses

The analysis below will start by answering the first research question about an ethical balance between the heating needs of the residents versus the climate justice of reducing energy consumption. This question relates to distributional justice. The next section will approach the second question of how socio-technical and material settings of the specific case interact with these questions of justice. This section is divided into four subsections. The last section reflects on the last research question about who and what should be included in the justice arguments and decisions. This question relates to procedural and recognition justice.

5.1. Justice in the balancing of energy savings, comfort and health

The most fundamental issue of justice in relation to heating may be the balancing of the right to maintain a comfortable and healthy indoor climate versus the need to save energy for the sake of the global climate. The idea behind the 18–21 °C interval associated with low payment, compared to a system where each additional temperature increase will cost more, can be seen as an attempt to create such a balance. However, it can be debated whether such a system will increase energy consumption and thus negatively influence global climate. Analysis on consumption data suggests that this has not been the case in these buildings, though data are not statistically robust in this small experiment [28].

The justice in the range of the temperatures may, however, be open for discussion in relation to justice and comfort, as noted in one of the staff interviews:

“...so we could say 22°C (rather than 21°C) as this is also comfortable, and that would not be harmful for the buildings. In that case,

we would have more residents within the limits and then they would be happy. That is also important”

(Staff informant 2)

This staff informant questions the fairness of the temperature level set to 21 °C, and if 22 °C would be more comfortable for a greater number of people, thus making it fairer. Apparently, this staff informant places more importance on the residents' comfort than the issue of saving energy.

A similar view was found in one of the resident interviews:

“They say the ideal temperature is 20°C or 21°C, and there are actually not many people my age who can stand this. To sit in a room at 20°C, that is too cold (...) I have an average temperature of 24°C, and you could say I really must pay to keep the heat”

(Hanne, F)

As we see in these two quotes from both a resident and staff member, there are some who question the fairness of setting 21 °C as a decent temperature so that above this you must pay more, and they suggest this temperature limit should be higher. Besides questioning the exact temperature range that should constitute the interval with the lowest payment, these two quotes also reveal that not all residents are aware of the actual limits of the temperature (21 °C compared to 20 °C). Furthermore, the staff informant does not give priority to the global climate issue and keeping energy consumption down, as he only considers what is harmful to the buildings and comfortable for the residents.

What is comfortable varies among residents, and some prefer a lower temperature:

“I work as a builder and I'm outside the whole year, so I prefer to have it a bit cold. If I come home from work after a whole day outside, then the temperature should not be much above 20°C, otherwise I end up asleep on the sofa”

(Søren, M)

Søren also questions some of the logic behind the project, as he thinks it cannot be as important for the buildings to be heated as the staff tell him. He likes to sleep in a cold room, and he does not follow the advice to heat all rooms the same temperature to keep them above 17 °C. “This cannot be very climate friendly”, he says. He therefore questions the project's balance between justice in global climate and a healthy indoor climate.

In addition to the temperature ranges, the residents also question the humidity levels. Some of the residents were quite interested in monitoring their indoor climate measurements and comparing them with their neighbours, as seen in this case:

“I pay a little extra compared to [my neighbour] because I need the heat (...), whereas my CO₂ and humidity levels are fine. He has a bit more humidity in there as he drives a scooter, so sometimes he has wet clothes hanging to dry and the humidity can be a challenge.”

(Henriette, F)

This raises the question of whether heating requirements should be considered more essential than e.g., the need to dry wet clothes, and thus be thought of as something that should not cost extra. This also relates to having a healthy indoor environment, which in medical terms can be related to not having too high humidity, and thus the extra payment for high humidity should primarily be related to this issue. Whether this would work as an incentive for the residents is dealt with in a later section.

5.2. Which socio-technical parameters influence ethical balancing related to heat expenditures?

The following four sections will answer the question of how socio-technical parameters influence the balance between present and future generations, as well as other ethical issues related to the distribution of

heat expenditure. These four sections focus on the justice of payment, to what degree data and metering are reliable, whether data can be misused, and if feedback is used and understood by the residents.

5.2.1. Justice in relation to price and types of accounting

Many of the interviewed residents expressed the view that it would be most fair to pay only for your own consumption. However, these residents did not agree on which system aligned most with the idea of 'paying for yourself'. This may be because they had difficulty understanding the two systems. Below are two different quotes representing views for and against dynamic accounting of heating:

"Someone benefits from the rest of us getting punished in this system [dynamic accounting of heating]. That is not fair. You should pay for what you consume"

(Hans, M)

"I think [dynamic accounting of heating] maybe is fairer. That you pay for what you have used (...) I don't pay for the CO₂ or whatever my neighbours have used"

(Helle, F)

In these quotes, both Hans and Helle argue that it is fairer for each resident to pay for their own consumption. However, they use the same justification for two different accounting systems. In contrast, one of the staff informants suggested that it might be fair to have a system that equalises the payment among residents, especially within social housing:

"In relation to an *almennyttig bolig* (the Danish form of social housing), I think this system [dynamic accounting of heating] is a fairer way of distributing the cost"

(Staff informant 5)

This statement partly resonates with the quantitative evaluation that shows a more even distribution among residents with the dynamic accounting of heating system compared to the old system. In some cases in the old system, there was a factor 8 difference between those who paid the most compared to those who paid the least, while in the dynamic accounting of heating there was only a factor 2 difference [28].

During the interviews, it was also often apparent that the residents who were against dynamic accounting were those who had to pay more with this system, while those who paid less were more positive about it. However, for many of the interviewed residents, it was difficult to compare how much they paid in the new and old systems, as the old system involved an advance payment, where the resident paid a certain amount every month and then received money back at the end of the year if they had paid too much. This is different from the dynamic accounting of heating system, where people pay based on their metering every month, implying that residents cannot know in advance how much they will have to pay, which can be a problem for residents with a tight budget. In addition, many of the interviewed residents liked receiving their money back at the end of the year with the old system.

5.2.2. Data reliability and justice

Questions of data reliability also play a role when examining how fair residents and staff believe the system to be. Data reliability in relation to dynamic accounting of heating has several aspects: Are the sensors measuring correctly? Are they located correctly in relation to the layout of the apartments, so the measurements are representative? Can residents interfere with the sensors in a way that changes the measurements? Can factors that residents cannot control interfere with the measurements? Are the other sources of data used for calculating the cost distribution (structural attributes of the apartment and building, weather data, etc.) reliable?

Several residents expressed concern regarding the reliability of the indoor climate measurement data. Some had experienced errors such as defective meters (Hanne, F) or incorrect records of square meterage that

affected the cost distribution (Stig, M). While experiences of defects affected the residents' attitudes towards the system, both operations staff and residents described the lack of defect remediation and follow up as the main point of discontent.

Two external factors that affected the measurements were sunlight exposure and outdoor humidity, since these were outside the residents' control. When either the outdoor humidity level or sunlight exposure resulted in higher costs for the residents, this was perceived as a great injustice:

"My sensor was placed so the sun was shining on it and it's not supposed to (...) It has always been green for humidity and CO₂, and then the heat has been red because I live on the top floor – it's like living in a greenhouse. It wasn't taken into consideration, and it should've been."

(Stig, M)

The same feeling of injustice described by Stig also emerged when building issues interfered with the measurements. In one block, some apartments had exposed heating pipes, which made it impossible for the residents to keep the temperature within the basic payment range. As a staff member describes:

"It can be difficult to turn the heat down when there is an uninsulated heating pipe in the floor of your lease, and then you are, and I quote, punished a bit because of it"

(Staff informant 3)

Whether the measurements are reliable, whether errors are corrected quickly and whether external forces outside the residents' control affect the measurements can all have a significant impact on how fair the system is perceived to be. However, these issues characterise both the new and old systems, and as noted by the staff in the quote below, residents tend to be critical of new things, whereas they do not notice the same types of problems in the old system:

"The blind trust in the traditional radiator meter, evaporation meter, that no one ever tested besides the companies who supplied it ... Everyone believes in that, but now everyone is sceptical about this indoor climate meter"

(Staff informant 5)

5.2.3. The use and possible misuse of data

When operating and maintaining a building, indoor climate data can offer valuable insights into building deficiencies, leaks, etc., but also into whether certain residents need additional help to achieve a good indoor climate for the sake of their own health and wellbeing, and in order not to damage the building. Especially in multi-family housing, where expenses for maintenance and repair are shared, it can be considered a question of justice to ensure both the health of the residents and that the building is not damaged. It is therefore possible to act on the gathered data, but this also raises questions of privacy. Staff informants did not agree on the question of whether housing staff can and should use the indoor climate data from individual apartments. While some found such data access very useful, others found it problematic:

"It has been a great tool for us, because now we can stay up to date, now we can see if there's damp in the apartments"

(Staff informant 5)

"I have to admit, I'm a bit unsure about GDPR rules and the like. Can I call a resident and say: 'I can see that your water consumption is very high'? Are you even allowed to do that?"

(Staff informant 4)

If data from individual apartments is used by operating staff, there is also ethical questions in relation to *how* it is used. It could be used to identify residents who need help understanding dynamic accounting of heating and figuring out how to achieve a better indoor climate. The

staff would be able to help them with that (see also next section on feedback). However, it could also be used to place blame if a resident is not behaving as prescribed:

“We can go in quicker and see if the problem is with the behaviour or the building”

(Staff informant 1)

Especially in cases of damp and mould growth, the operating staff saw a benefit in having access to continuous indoor climate data, instead of installing loggers when mould issues have already occurred:

“If nothing else, we can use them in cases where we enter an apartment and think that there’s mould in there. Then we can go in and say ‘maybe if you just change your behaviour...’ Instead of having to go out and install a logger to find out how they behave, we have the information immediately”

(Staff informant 1)

As mentioned by informant 4, indoor climate data is a form of personal data and therefore governed by data protection legislation, GDPR [30]. Informant 2 acknowledges the risk of data misuse: “to sit and pry into whether they use a bit more or a bit less, nobody wants that”.

The use or misuse of data gathered through the dynamic accounting of heating is to some extent a question of weighting the common good of all residents from avoiding possible damages against the individual resident’s right to privacy.

5.2.4. Is feedback used and understood?

For dynamic accounting of heating to work as well as possible, residents need to receive information on their metered indoor climate, and they need to understand and react to this information. This is an issue of communication, including how staff can help residents, and it relates to the specific layout of the monthly report that the residents receive. The interviews with both staff and residents provided clear evidence that residents often do not understand the new system and the feedback they receive in the monthly reports. Problems related to the communicative layout of the reports were acknowledged during the project and the design was improved. Similarly, there was a learning process from one case study to the next in terms of communication at meetings, etc. The project therefore highlights the importance of clear communication in projects like this.

Some residents did actually read and understand the monthly reports and responded to them, especially in relation to humidity, as seen in the quotes below:

“I do look at for instance humidity, I think I have become more conscious of it. Obviously, that will happen when you get these reports every month”

(Susanne, F)

“Based on the figures I can see, well, here is something I could do better (...) then I can do something about the humidity for instance, if I see it is too high”

(Henriette, F)

One resident explained that he did not really change his habits, but he still looked forward to receiving the monthly reports as they confirmed that he was already doing well: “I look forward to the report with all the green lines” (Helge, M). Others clearly stated that they did not react to the reports, as in this quote:

“We try to live as normal as possible. We don’t touch the temperature because we don’t want to freeze (...) We have not changed anything”

(Hans, M)

Some residents also felt stressed and annoyed when they received the reports, as expressed in the following two quotes:

“I cannot recommend [dynamic accounting of heating], because I feel like someone is controlling my life, and that is something I really dislike”

(Helena, F)

“I think [dynamic accounting of heating] is quite stressful because you do everything to keep... you cannot light a candle anymore, and if you have guests, it also tells you about it in both the humidity and CO2 levels”

(Stig, M)

5.3. Who and what should be included in the justice arguments and decisions?

Procedural and recognition justice are important in relation to dynamic accounting of heating in terms of who should decide how the system is implemented and about the payment intervals. The legal aspect of residential democracy in Danish social housing states that residents are the ones who must decide whether or not to test a new accounting system [27]. However, residents need to receive information about these systems to make an informed choice, and different actors can be relevant here. Obviously, the housing association will be among those to inform the residents of the advantages and disadvantages of the system. Some residents felt it worked well when they received this information at meetings before the decision was made. However, others felt that the housing organisation had already decided and were just trying to persuade the residents:

“I think they [the housing organisation] have tried to impose it on us. They have been in favour of it all the time, that this was the right solution, and that we should give it a chance”

(Søren, M)

However, the housing organisation were not the only ones to contact the residents to influence their decision. Interviews with staff revealed that some of the big companies who run the traditional accounting of heating also approached residents to influence their decision:

“It is obvious that there have been some major forces involved ... We have had residents where [company name] has approached them to tell them how bad the new system is and how good the old is. That is absolutely terrible”

(staff informant 5)

As a response to the project, three of the big companies behind the traditional accounting of heating formed an alliance, through which they lobbied against the ideas behind the new system. These three companies created a website using the name of the new system (www.dynamiskevarmeregnskaber.dk) to advocate strongly against it and criticise its reliability. Furthermore, they published newspaper features and sent a letter to the minister of housing. They sent this letter when the minister had to decide, based on an evaluation of the dynamic accounting of heating system, whether residents should be able to choose the system in the future as an alternative to the old system. This illustrates the strong economic interest involved in maintaining the status quo on the market for accounting of heating and a fear of losing market shares.

Residents had to decide not only whether or not to test the new system, but also the limits of the payments were open for discussion, and the residents therefore had to be advised regarding this. When it comes to levels of humidity and CO₂ concentration, there are some science-based technical standards to support the idea of what is healthy for both humans and buildings [31]. When it comes to temperature, this is more ambiguous since very low temperatures combined with high humidity can cause mould, whereas higher temperatures mean higher energy consumption, which is associated with global climate consequences. A meeting was held prior to initiating the dynamic accounting

of heating, where residents could discuss where to draw the lines, and a range of 18–22 °C was chosen. However, this caused concern among the housing association and the project partners that this decision could lead to rising energy consumption. The payment lines were thus changed to 18–21 °C, which went against the residents' decision but was in favour of the climate and future generations. Not all residents found this to be fair:

“When we had a meeting, we said this and this, but then something changes, and two days after they change it to something we did not choose. This is a bit sad, and many were upset by this (...) at a meeting, we had decided that the limit should be 22°C and then two days after that we get a letter telling us that it will be changed to 21°C”

(Stig, M)

Having residents decide the payment limits may seem fair, however, global climate issues may be overlooked, and professionals should therefore also have a say. However, opening an issue for discussion and then overruling the decision seems neither fair nor sensible.

6. Discussion

The aim of this paper was to present a case study on accounting of heating in a specific Danish experiment and to analyse different aspects related to justice. Based on these aspects of justice, we have highlighted what we consider to be relevant questions and discussions in this specific case, but we have also presented more general knowledge about energy justice, which will be valid within a European context and beyond.

One example of this general knowledge is how energy justice is always about balancing between different goods, as illustrated by the goddess *Justitia* holding weighing scales in one hand. The most fundamental aspect is to balance the needs of present generations in the global north versus the global south and of future generations. This includes balancing healthy and comfortable indoor climates versus assuring a global climate that will also allow future generations to have a decent life. Decisions on what is fair in this balancing act must include those who are directly affected (i.e., the residents) but it must also include someone who can speak for the global climate (e.g., housing organisations, scientists or legislation). In the other hand, the goddess *Justitia* often holds a sword representing the power in decisions. Who has and should have the power are important discussions, and as seen in this case, many actors are involved: residents, building staff, housing organisations, scientists, legal authorities and not least private companies. However, questions can be raised as to what extent it is fair and just that private companies are able to have an impact on this decision due to their resources. As suggested by Galvin [14], the question of what is actually implemented is always part of a political process and thus also an issue of power. However, ethical and moral arguments should also be included. In liberal democracies, private companies are seen as important stakeholders in ensuring a green transition by providing new technologies. However, when discussing morality, we can question to what extent they should interfere in democratic processes, even when this is legal.

Another balancing act in questions of energy justice is the balance of paying for your own use versus ensuring everyone's basic needs for heat are satisfied. This kind of balancing act can be seen in the idea of a certain temperature range being associated with the lowest cost, rather than a continuum where still higher temperatures will raise the cost. With the introduction of not only temperature but also CO₂ and humidity considerations, the energy justice further includes the idea that a healthy indoor environment as well as a decent temperature should incur the lowest cost in order for it to be affordable to all. The question of the payment is, however, not only about fairness in the distribution of cost among residents in each apartment block. It is also based on the idea of motivating residents to do the right thing, maintaining a healthy indoor environment without wasting energy. In that sense, it is part of a

balancing act between a healthy indoor climate and the global climate. As our analysis shows, whether such ideas of energy justice resonate with residents depends on the type and quality of the information and help that the residents receive. If the feedback loop informing residents about why they pay more or less does not work, then the whole idea of energy justice in this type of accounting will disappear. Communication and learning processes become just as central as the technical specifications of the system.

As we have learned from this case, energy justice can be highly inflated by the structural attributes of the building, heating pipes, weather, metering aggregates and data. Non-humans in general are very much a large part of most energy justice discussions in this case, and they are also involved in contextualising when and how the weighting in energy justice between different goods will be balanced. Specifically, the extensive data collection from indoor climate meters represents an interesting ethical weighting, as data can compromise privacy on the one hand, while also serving as a priceless necessity in the future green transition.

To sum up, this study provided new information on how energy ethics and justice are intertwined with the attributes and operation of the buildings, the residents' practices and learning processes in relation to heating systems and achieving comfort, communication and learning in organisations, as well as administrative rules and the power of large companies. The task is to balance these different aspects effectively while ensuring the sustainable well-being of both present and future generations, and the study will therefore also contribute to the literature on socio-technical construction of comfort and sufficiency in energy demand.

7. Policy related conclusion

At the European policy level it is noted that individual metering and payment for heating in apartment blocks are beneficial [1], and a review study document how there are diverse ways of dealing with this in different member countries [2]. With new technical possibilities of indoor climate measurements combined with online cloud-based data collection, it is expected that metering methods will develop in the coming years, and this Danish case study can thus point at some important measures to observe in such a transition.

However, it is also important to note the limitations of the present study. The experiment only included three residential areas that represented fewer than 1000 apartments, and within these apartments a small qualitative sample of staff and residents were chosen for interviews. Further experimentation using different schemes for allocating heat payment and accompanying research-based evaluations are thus needed, in particular, experiments where the communication with residents is dealt with more professionally.

Such experimentation can inspire changes relating to the distribution of heating costs in apartment buildings, which can be expected at least at a European level. These include ideas of a partial warm rent [5], put forward as an attempt to deal with the “split incentive problem” [3]. This idea aims to make energy retrofitting more attractive to landlords without placing high financial burdens on the residents [6,7]. With such possible future changes, our case study highlights several factors to consider and include in future evaluations when developing new accounting methods.

First, when exchanging a linear rising price following temperature level with an interval to stay within, or a level to stay below, there must be a debate about what a decent or healthy temperature level is. This cannot be stated objectively or scientifically, as comfort temperatures are known to be both socio-technically constructed [17,32] and vary with e.g. gender and age [33]. At the same time this temperature level needs to balance justice-wise between current and future generations, in relation to respectively indoor climate and global climate change. The present Danish case included tenants' democracy, however, in a majority of rental housing in Europe and beyond, this is not the case.

Should such temperature levels thus be decided by landlords or politically, at national or international level, then becomes a relevant question, with high expected impact on climate and energy poverty.

Second, as seen in this study, whenever a payment system is changed proper communication to residents is important. A simple thing such as shifting from advance payment to payment according to monthly penalty taxes might imply distress. Furthermore, only if people understand the payment and its logic will the possible incentives work.

Third, indoor climate data can be important in an efficient energy management of buildings. However, questions regarding who should have access to what data needs to be considered thoroughly to deal properly with data privacy issues. More research into possible benefits and risk associated with the use of this type of data in housing operation practice is needed.

Finally, the socio-materiality will vary from case to case, and across different national contexts, ages of buildings, heating infrastructure, housing systems etc. Thus, there might be differences in what works and what does not work in different context. More case studies in general are thus needed to understand these relations, as we are in need of EU regulation which can work in all these different contexts to assure just heating cost allocation to the benefit of both current residents and global climate. The socio-technical construction of comfort norms is also a product of EU regulation, and we need regulations that can change the direction of comfort norms towards better sufficiency and living well within planetary boundaries.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this paper.

Data availability

The authors do not have permission to share data for reasons related to the consent from the informants.

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