Dynamic Accounting of Heating In Social Housing

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DYNAMIC ACCOUNTING OF HEATING IN SOCIAL HOUSING

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and Sirid Bonderup

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PREFACE

This report presents the concept of ‘Dynamic Heating Accounts' in the context of social housing in Denmark.

The Danish National Building Foundation has funded a project to test whether and how Dynamic Heating Accounts can be used in social housing. As part of the project, the Foundation wish to share the preliminary results with California Environmental Protection Agency, CalEPA.

The report covers the principle behind, a thorough description of the methods for defining the specifications for temperature, relative humidity and CO_2, as well as the framework for dividing the heating costs among the apartments.

1

INTRODUCTION

1 INTRODUCTION

‘Dynamic Heating Accounts’ is a combined measurement, visualization and payment concept for indoor climate quality and energy use in social housing with multi story dwellings. The concept aims to motivate tenants to maintain a comfortable and healthy indoor climate without excessive energy consumption in their apartment, and at the same time reduce the risk of humidity-related deterioration of building materials.

A further ambition is to better distinguish between on one side the economic sustainability of investments in the building envelope and technical installations improving the overall energy performance and on the other side the effects of balancing everyday behavior, comfort, health and energy expenditures among tenants. By measuring the quality of the indoor climate, it is possible to make a distinction between energy savings caused by investments in improved energy efficiency of a building and increased energy use caused by tenants having a higher temperature preference when the more energy efficient building reduces the costs of high temperatures after renovation. Reducing the heating bills based on good tenant behavior may further motivate to maintain an indoor climate that is both environment-friendly, reduces the need for excessive building maintenance and is comfortable and healthy for tenants.

By giving building owners the ability to foresee the impact of investments in improvements of the building envelope and technical installations on energy expenditures, their financial security is improved and the barriers for such investments reduced. The long-term savings can either benefit the building owners as return of investments or be used to reduce payments by tenants. In Danish social housing only reduced payments by tenants is a legal option.

The concept is in line with the United Nations’ 17 Sustainable Development Goals. In particular SDG 3 ‘Good health and well-being’, SDG 11 ‘Sustainable cities and communities’ and SDG 12 ‘Responsible consumption and production’. In Denmark, the legally binding ambition is to reduce greenhouse gas emissions by 70% in 2030 (in relation to emissions in 1990). Furthermore, the ambition is to work towards net-zero emissions in the EU and in Denmark by 2050 at the latest [1].

23% of Denmark’s CO_2 emissions are caused by energy use in buildings, and another 10% by energy used in construction of buildings and other structures and by energy embedded in building materials [2]. To reach the target of a 70% reduction, it is vital among other things to halve the amount of energy used for domestic heating. Halving the energy use requires large investments in the building envelope and technical installations in order to improve the energy performance of existing buildings. An executive order from the Danish Transport, Construction and Housing Authority has provided an opportunity to develop the concept of Dynamic Heating Accounts in order to improve the indoor climate in social housing as well as reduce the energy consumption in these buildings [3].

This report presents information and preliminary results from the project ‘Dynamic Accounting of Heating in Social Housing’. The project is still ongoing.

2

BACKGROUND

2 BACKGROUND

In Denmark, heating costs in social housing apartment buildings have traditionally been divided between tenants based on either the size of the apartment or the measured energy use. Heating expenses are usually payed in equally sized monthly installments. Yearly, the difference between what has been paid on account and the actual heating use is calculated and either a supplementary bill is sent to the tenant or the surplus is refunded.

Many social housing departments have previously installed fluid evaporation meters on each radiator to record the energy use and motivate tenants to save energy by reducing the ventilation rate or lowering the temperature setting on their thermostat [Figure 1].

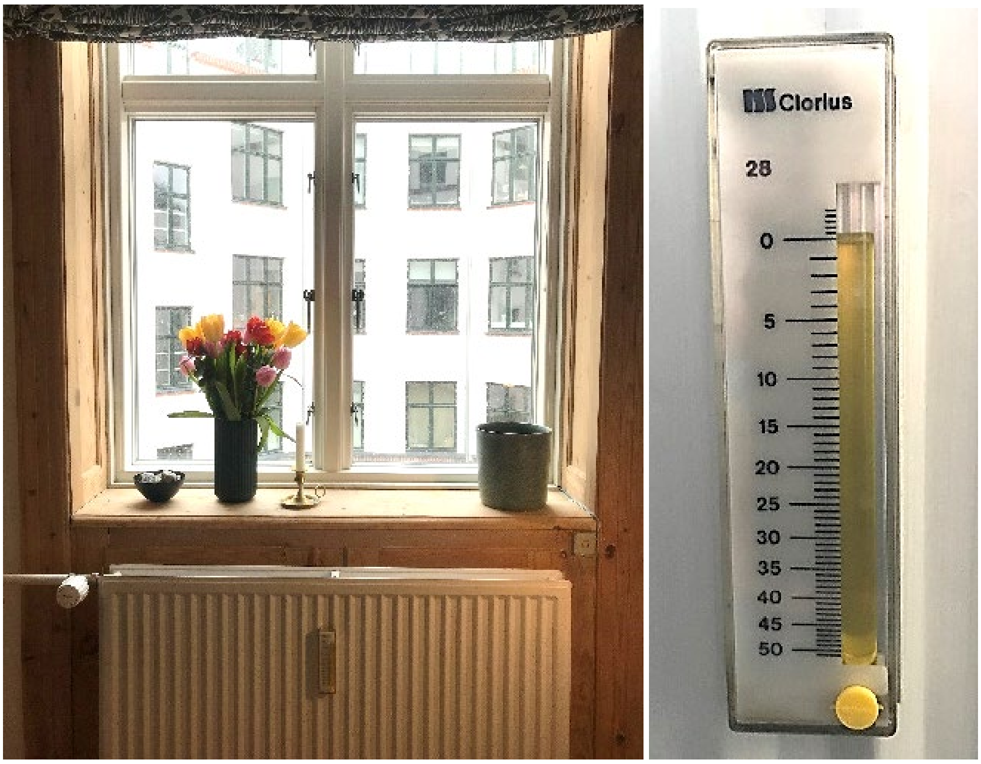


FIGURE 1. The energy use is measured using a fluid evaporation meter mounted on each radiator in the apartment. The energy use is determined once a year leading to an extra payment or a payback, adjusting the expected consumption payed for as a monthly flat-rate fee.

In recent years, the evaporation meters have often been replaced by electronic meters with automated readout that monitors the surface temperature of the radiators.

An unintended consequence of the traditional accounting of heating is that tenants who maintain an indoor temperature slightly lower than their neighbors can exploit the heat transfer through the walls, floor and ceiling from adjoining apartments to reduce their own heating cost [Figure 2].

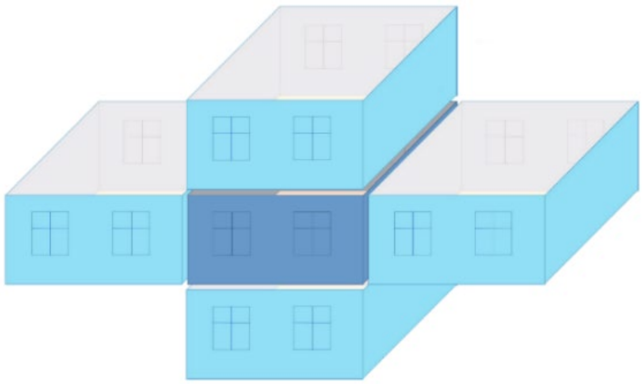


FIGURE 2. Schematic picture of large areas facing neighbors compared to walls and windows to the outside.

Figure 3 shows how an apartment where tenants keep their temperature at 19°C and where all neighbors have a temperature at 21°C, have a 50% reduced heat consumption [4].

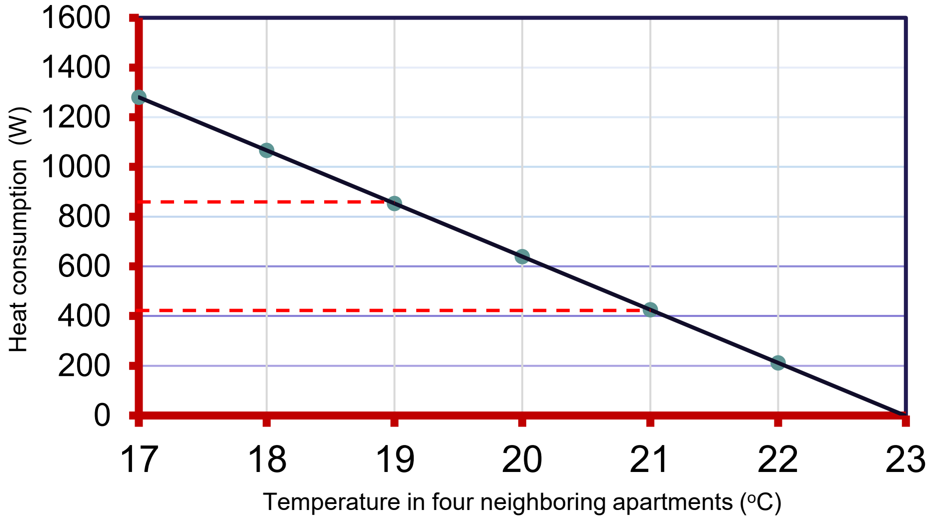


FIGURE 3. Heat consumption for an apartment in a multi-story dwelling, with an indoor temperature at 19˚C, as a function of the temperature in the neighboring apartments.

Furthermore, it is expensive to install, readout, and calculate heat consumption based on fluid evaporation meters or other measurement devices on individual radiators compared to the modest cost of heating in new and energy-renovated houses.

In 2012, CEO Göran Wilke from IC-Meter introduced the Dynamic Heating Accounts concept as an alternative to the traditional heating accounts. In 2017, an executive order from the Danish Transport, Construction and Housing Authority made it possible for social housing departments to apply for dispensation from the general provision and divide the heating expenses based on the measured indoor climate in the individual apartments [4]. The executive order provided an opportunity to develop and demonstrate the Dynamic Heating Accounts concept in a combined demonstration and research project.

The project received financial support from the National Building Foundation (Landsbyggefonden) in Denmark.

3

PRINCIPLE

3 PRINCIPLE

The principle behind the Dynamic Heating Accounts concept is to continuously measure temperature, relative humidity, and CO_2 in a central position in each apartment and base the heating accounts on these measurements. In this way, tenants will get an economic incentive to maintain a comfortable and healthy indoor climate in their apartment. With the dynamic accounting of heating, tenants will pay for the indoor climate that they can control independent of conditions in neighboring apartments. This is an important change from the traditional heating accounts where tenants in social housing pay for the energy use irrespective of the energy performance of their apartment and with a big impact of conditions in adjoining apartments. The purpose is to motivate tenants to maintain an indoor climate that benefits their own health and the building while maintaining an incentive to reduce energy consumption.

4

PROJECT OVERVIEW

4 PROJECT OVERVIEW

The project consists of three parts. Part I is a research and development project that examines the incentives that motivate tenants in social housing to improve the indoor climate quality in their apartment. The research project started in May 2018.

The project aims to:

- Develop a framework to divide the heating costs between the tenants. A framework that will motivate the tenants to improve the indoor climate in their apartment.
- Develop a guideline for the administration to facilitate the communication between the tenants and the social housing department.
- Define specifications for the cloud solution to visualize the indoor climate and the associated cost for both tenants and building managers.

Part II will demonstrate the feasibility of dynamic accounting of heating in existing housing estates. The project focus on the installation and administration of the climate sensors [5]. Data from the climate sensors are used to document and develop the framework for dividing the heating cost between the individual apartments. The demonstration project started in January 2019.

The project aims to:

- Test the Dynamic Heating Accounts concept on a large scale.
- Finalize the development of a cost-effective indoor climate sensor and cloud solution as well as the implementation and administration of the concept.
- Provide tools that can strengthen incentives to maintain an appropriate indoor climate and energy behavior in social housing, where the tenants are responsible for the indoor climate in their apartment while the housing association is responsible for maintenance and investment in the building envelope and technical installations.

Part III is an overall evaluation of the concept and the demonstration projects focusing on delivering recommendations for the feasibility and applicability of using dynamic accounting of heating in social housing in general.

Part I is carried out by the non-profit housing organization Domea that manages about 80 social housing associations with more than 60,000 homes across Denmark [6].
Part II is carried out by Technical University of Denmark, Aalborg University and the consulting company EXERGI [7].
Part III is carried out by Aalborg University with data from Part I and II.

4.1 Social housing in Denmark

Denmark has 5.8 million inhabitants and about 1 million of them live in social housing. The social housing associations are non-profit and include student, family and retirement homes. Everyone can apply for social housing.

There are more than 570,000 dwellings available as social housing. These dwellings are grouped into 7,085 different departments; a department consists of e.g. an apartment building, several neighboring apartment buildings or an area of terraced housing. The departments are organized in 561 different housing associations managing the houses all over the country [8]. This project solely focuses on the percentage of social housing that consists of apartment houses.

FIGURE 4. Danish social housing in numbers.

5

METHOD

5 METHOD

A pilot study was conducted to examine whether a smart indoor climate meter installed in a central location in an apartment can give an acceptable average measurement for the whole apartment, or more measurement locations are needed. The pilot study showed that a smart indoor climate meter installed in the main living room of the apartment provided a useful average reading for an entire apartment with four rooms or less [9].

Figure 5 shows a smart indoor climate meter in a social housing apartment in Svendborg, Denmark. The meter was installed following renovation of 250 social housing apartments in the social housing department Toftemarken.

FIGURE 5. The picture on top shows the living room prepared for a family celebration in a home in Svendborg, Denmark. The picture below shows a close up of the smart indoor climate meter installed in the living room.

The Dynamic Heating Accounts concept is currently being tested on a large scale in more than 1,000 social housing apartments in Denmark.

FIGURE 6. Examples of apartment buildings in the demonstration project. Top: Exterior view of an apartment building in Haderslev. Bottom: Exterior view of an apartment complex in Svendborg.

Table 1 presents information on the social housing departments participating in the demonstration project. These departments are expected to be included in the final report.

TABEL 1. Information on the apartments examined in the demonstration project and start date of the measurements.

Social housing department	No. of apartments	Measurement start
Domea housing association Haderslev, department 16-25 Address: Skovvænget/Brombærvej	84	January 1st 2020
Domea housing association Svendborg, department 75-02 Address: Toftemarken/Klintemarken	250	January 1st 2019
Domea housing association Svendborg, department 75-04 Address: Jægermarken	246	January 1st 2021
Domea housing association Copenhagen, department 35-25 Address: Gadekærvej	203	June 1st 2019
Bo-Vest housing association Moserne department Address: Tranemosegård	560	January 1st 2020

All departments except 'Gadekærvej' were undergoing renovation of installations at the same time they shifted to Dynamic Heating Accounts. This is making comparative analysis of the 'before' and 'after' situation difficult.

A smart indoor climate meter was installed in a central location in each apartment. The meter sensors measures three important indoor climate parameters: temperature, humidity and CO_2 concentration every five minutes. All data is transmitted and collected in the IC-meter cloud service through low frequency GSM, Wi-Fi, or Lora networks. Data from the smart indoor climate meter is available online via an app or an internet browser [Figure 7].

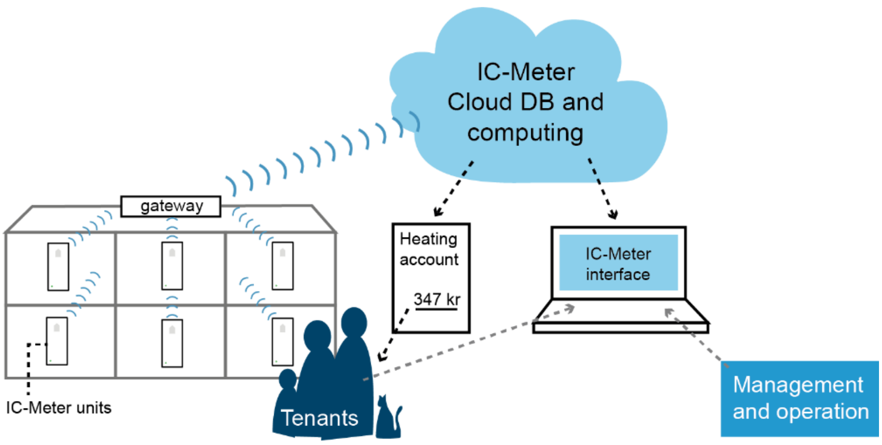
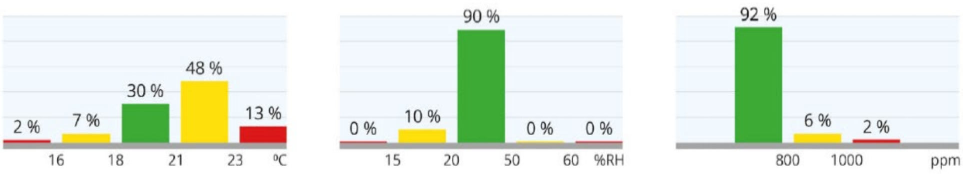


FIGURE 7. The IC-Meter system. The unit in each apartment transmits sensor data to a gateway in the building. The gateway sends the data to the IC-Meter cloud solution. In the cloud solution, the data is processed and both the heating account and data display are generated.

The data is displayed in the printed heating account with the IC-meter interface shown as the percentage of time spent in a good (green), less good (yellow) or poor (red) indoor climate [Figure 8].



Temperature – March 2020
Average: 22.4°C

Air humidity – March 2020
Average: 28.4%RH

CO_2– March 2020
Average: 574 ppm

FIGURE 8. An example showing visualization of the indoor climate as percentage of time spent in a good (green), less good (yellow) and poor (red) indoor climate for temperature, relative humidity and CO_2 [10].

Another series of diagrams show each of the three parameters individually to make it easier for the tenants to learn from the measurements how to improve the indoor climate in their apartments [Figure 9].

FIGURE 9. CO_2 concentration in an apartment in a 24h period. The concentration is measured every 5 minutes. The colors indicate whether the measurement is within the concentration limits in the green, yellow or red zone respectively [11] .These detailed graphs are only available to the tenants of the individual apartment.

Operation staff access an edited interface that both allows for fault detection and secures tenant privacy. The identification of faults in installations and wrongful tenant behavior is made by algorithms in the cloud and communicated to operational staff based on average measurements over longer periods to avoid infringing on tenants right to privacy.

The next four sections will explain the reasoning behind the specific threshold limits for the three parameters and the method for calculating and dividing heating costs.

5.1 Specifications for temperature

A high indoor room temperature in winter will inevitably lead to an increase in energy consumption for heating.

Table 2 shows the temperature limits for the winter and summer season. In winter, the temperature limits for a good indoor climate span from 18˚C to 21˚C. The lower temperature limit of 18 ˚C was chosen to reduce the risk of mold growth on exterior walls. The upper temperature limit of 21˚C was chosen to maintain an incentive to reduce the energy use during the heating season. The temperature span will most importantly not be a risk to human health. The limits are based on the international standard ISO 7730 assuming rather thick clothing comparable to 1.3 clo or more at sedentary activity [12].

The heating system is often turned off in summer. The tested concept of Dynamic Accounting of Heating require heating, including floor heating of bathrooms, to be turned off in the summer. Table 2 lists recommended temperature limits for the summer season but a less good or poor temperature will not result in an additional fee.

On sunny days, tenants will furthermore have no means to control the indoor temperature. A high temperature on sunny days will therefore also not result in an additional fee. The outdoor climate conditions are collected from national weather stations located in the area.

TABEL 2. Temperature limits for winter and summer. A temperature outside the green zone will result in an additional fee in the winter.

Temperature (°C)				
Zone	**Winter** (November - April)		**Summer*** (May – October)	
Good	18-21		19-23	
Less good	16-18	21-23	17-19	23-25
Poor	<16	>23	<17	>25

*The temperature limits for the summer season are recommended and will not result in an additional fee.

5.2 Specifications for relative humidity

High humidity levels can lead to mold growth and other moisture related problems in buildings.

In winter, the relative humidity should be between 30% and 50%RH in apartments with natural ventilation. In apartments with balanced mechanical ventilation, the relative humidity should be between 20% and 50%RH.

In summer, the relative humidity should be between 35% and 60%RH in apartments with both natural and mechanical ventilation. All indoor surfaces will be warmer and therefore more robust against mold growth in summer justifying a higher upper humidity limit in summer than in winter. It is also not possible to maintain very low indoor humidity in summer with much more water content in the warmer outdoor air.

The relative humidity thresholds for apartments with natural ventilation are shown in Table 3 and for apartments with balanced mechanical ventilation in Table 4.

TABEL 3. Relative humidity limits in apartments with natural ventilation in winter and summer. A relative humidity outside the green zone will result in an additional fee in both winter and summer.

Relative humidity (%) – natural ventilation				
Zone	**Winter** (November - April)		**Summer** (May – October)	
Good	30-50		35-60	
Less good	20-30	50-60	25-35	60-70
Poor	<20	>60	<25	>70

TABEL 4. Relative humidity limits in apartments with balanced mechanical ventilation for winter and summer. A relative humidity outside the green zone will result in an additional fee in both winter and summer.

Relative humidity (%) – balanced mechanical ventilation				
Zone	**Winter** (November - April)		**Summer** (May – October)	
Good	20-50		35-60	
Less good	15-20	50-60	25-35	60-70
Poor	<15	>60	<25	>70

On days with high water content in the outdoor air - for example due to heavy rain, the tenants will have no means to reduce the indoor humidity. A high humidity on days with an elevated outdoor water content will therefore not result in an additional fee. The outdoor climate conditions are collected from national weather stations located in the area.

5.3 Specifications for CO_2 concentration

The outdoor CO_2 level in Denmark is typically assumed to be 400 ppm. It is however increasing with 2 ppm per year. The indoor CO_2 concentration is the result of a balance between the supply from occupants in the apartment and dilution due to natural or mechanical ventilation. All humans produce CO_2 as part of our metabolism. A high CO_2 concentration indicate a high concentration of bio-effluents and can lead to fatigue and discomfort. The CO_2 concentration is often used as a general measure of indoor air quality where human occupancy is the main reason for reduced air quality.

A CO_2 concentration above 800 ppm will result in a less good indoor air quality while a concentration above 1,000 ppm results in a poor indoor air quality [13].

TABEL 5. CO_2 concentration limits in apartments with natural and mechanical ventilation. A CO_2 concentration outside the green zone will result in an additional fee all year.

CO_2 concentration (ppm)	
Zone	**Yearly**
Good	<800
Less good	800-1,000
Poor	>1,000

5.4 The framework used to divide the heating costs

The tenants' cost is calculated using a standard rate for the time spent in a good indoor climate (green), with an additional fee for time spent in a less good climate (yellow) and a further added fee for time spent in a poor indoor climate (red).

In winter, the temperature limits for a good indoor climate spans from 18˚C to 21˚C. The middle of the zone is 19.5°C. The basis for the calculation is that the heat demand is proportional to the temperature difference between outdoor and indoor during the heating season. The outdoor temperature is set to 5°C, while the additional heat from people, lighting and other appliances in the apartment is set to increase the room temperature with 3°C.

A 1˚C increase in indoor room temperature from 19.5°C to 20.5°C will increase the heat demand (Q_{rel}) with:
Q_{rel} = 1°C / (19.5°C - 5°C - 3°C) * 100% = 8.7%

In winter, the temperature limits for a good indoor climate spans from 18˚C to 21˚C, while the temperature in a less good indoor climate spans from 21˚C to 23˚C. The difference between the middle of the two zones is 2.5˚C. An increase in temperature from a good to a less good indoor climate will increase the energy use with:
2.5°C * 8.7% $°C^{-1}$ = 22%

The heating system is often turned off in summer. In the Dynamic Heating Account system, turning off heating in the summer is mandatory. The heating cost from the winter season is divided throughout the year and the additional fee for an increase in temperature from a good to a less good indoor climate should therefore be double.

The energy consumption is mainly related to winter but the core billing for heat is spread equally over the year. Therefore the additional pay for excess temperatures only allotted to winter months should be multiplied by 2, to reflect the annual excess consumption in the semi-annual winter payments.

It was therefore proposed that the additional fee for the yellow zone should be 44% higher than the green zone. From less stringent analysis, the additional fee for the red zone should be double or 88% higher. As a further simplification, the same fee was used for all three parameters [14].

Several methods have been tested to divide the costs between the three zones. In 2019, tenants in 250 social housing apartments in Svendborg, Denmark decided that the additional fee for a poor indoor climate should be paid as an average of the three parameters with a 44% additional fee for all three parameters in yellow and 88% for all parameters in red.

Preliminary data analysis was performed on measurements of the indoor room temperature in 171 social housing apartments in Svendborg, Denmark as part of the project [15]. More comprehensive data analysis will be performed later when data become available. The distributions in expenses for the traditional and dynamic accounting of heating for all tenants in 2019 are shown in Figure 10.

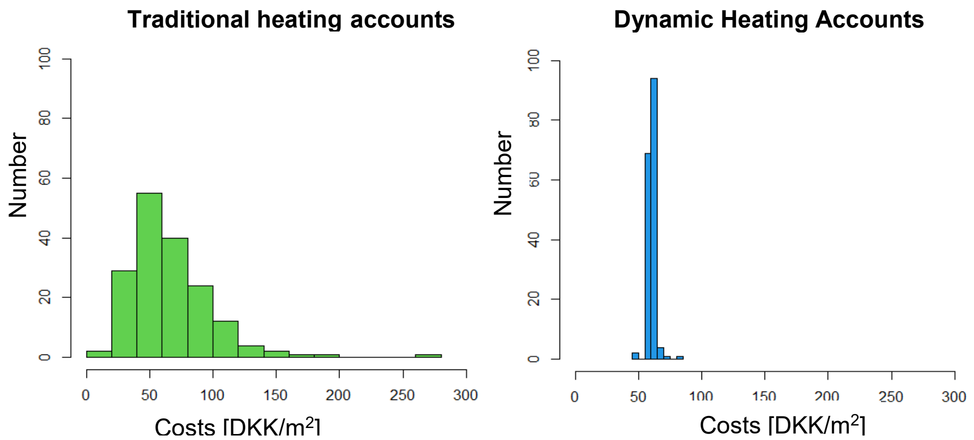


FIGURE 10. Distribution in the heating cost in Danish kroner/m^2 for 171 homes in Svendborg with traditional accounting of heating (left) and the dynamic accounting of heating (right).

The distribution in heating costs is wider for the traditional heating accounts than for the Dynamic Heating Accounts. Table 6 compares the 10 apartments with the highest heating cost and the 10 apartments with the lowest heating cost.

TABEL 6. Difference between the average payment for the 10 apartments with the highest and lowest heat cost respectively.

	Average heating cost	
	Traditional heating accounts	**Dynamic Heating Accounts**
The 10 apartments with the lowest heating cost	22.65 DKK/m	54.71 DKK/m²
The 10 apartments with the highest heating cost	155.03 DKK/m²	67.96 DKK/m²
Ratio	6.8	1.2

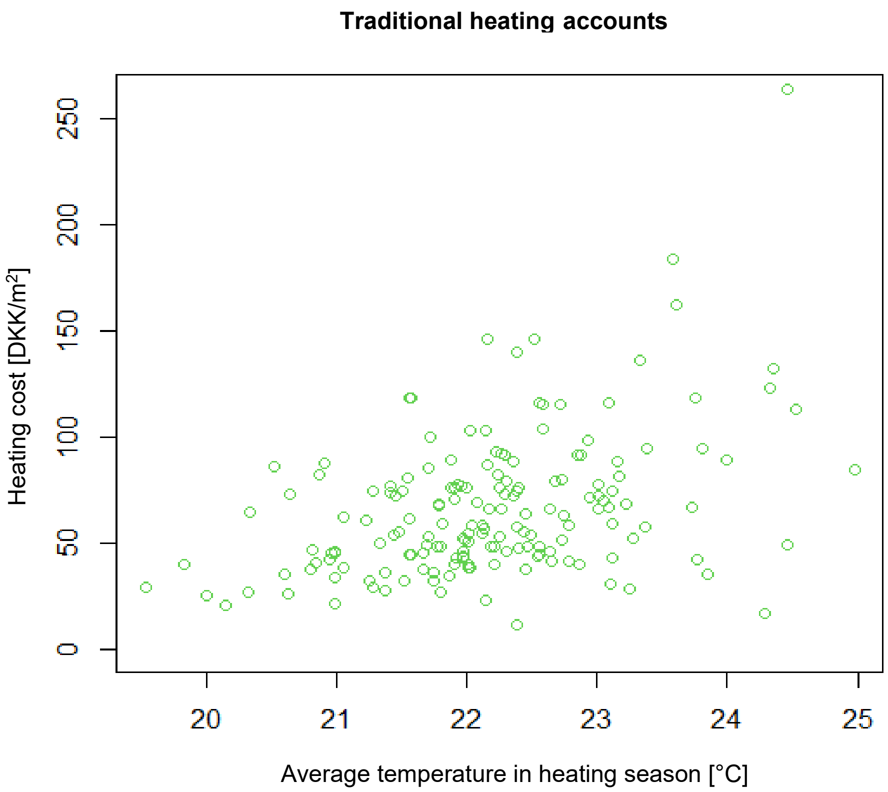
For the traditional heating accounts, the average heating cost for the 10 apartments with the highest heat use was six times higher than the average heating cost for the 10 apartments with the lowest heat use.

It is worth noting that in the traditional heating accounts, an adjustment of cost is performed based on whether an apartment has an 'exposed placement'. Which apartments that have an exposed placement (positions with high thermal loss e.g. at the end wall) are based on estimates and does not take into account the level of heat transfer between apartments.

For the Dynamic Heating Accounts, the average heating cost for the 10 apartments with the highest heat use was only 20% higher than the average heating cost for the 10 apartments with the lowest heat use. The redistribution of expenses with this framework for dividing the heating costs was therefore limited.

In 2020, the tenants were advised to increase the redistribution, which they accepted. It was proposed that the parameter with the poorest value, shown as green, yellow or red, should determine the overall cost. The heating cost will include a basic rate for the time spent in the green zone and an additional fee of 44% if one or more parameters are in the yellow, and 88% if one or more parameters are in the red zone. Thus, the poorest value determines the overall fee giving more redistribution compared to 'average color' previously.

Figure 11 shows the relationship between the heating cost and the average temperature in each of the 171 apartments in Svendborg.



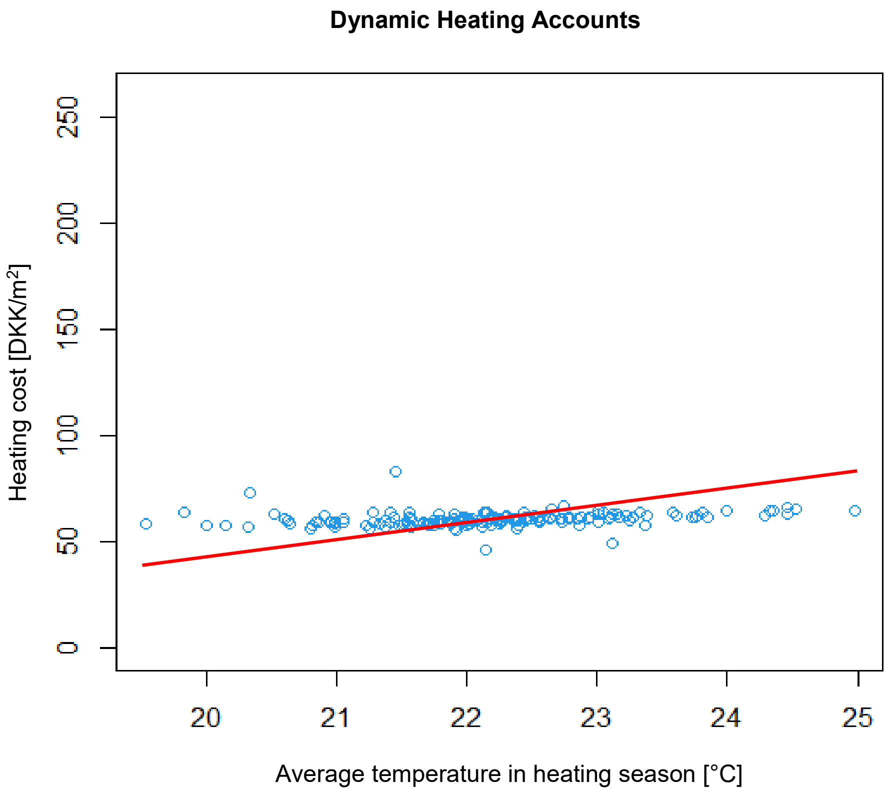


FIGURE 11. Relationship between the heating cost and average temperature during one heating season. The results from the limited redistribution in expenses in the dynamic heating accounts in 2019 are shown on the right. The red line estimate the impact of a larger redistribution in expenses as agreed in 2020.

6

EXPERIENCES

6 EXPERIENCES

During the installation process, it became clear that the placement of the smart indoor climate meters in the individual apartments needed careful attention, since the cabling for the power supply does not allow for easy replacement. To accommodate this it can be useful to test the placement through mock-up installations, before the final position is decided. This will also aid in determining whether the placement of the meters will avoid direct sunlight during the year. Placement can also affect the tenants' trust in the measurements and cause annoyance if they are placed inconveniently for the furnishing of the apartment.

The intension with the cloud service is to ensure that the indoor climate data is available automatically in one version for tenants and another less detailed for building managers. The importance of good data security and privacy of the detailed measurements were underlined from the beginning of the project. The building managers have access to monthly statistics but not the detailed five minutes readings. In cases with indoor climate problems, tenants can choose to share the detailed measurements with the building managers.

The setting up of a system assuring tenant data security and their access to the detailed data was however delayed. Therefore, the initial intensions of detailed access to own readings among tenants was not fulfilled in the first year of experimenting. The level of data access granted to building managers have been discussed and perhaps quarterly reports instead of monthly reports would be more acceptable. Quarterly reports might also better match the working practices of building managers, who are normally not sufficiently staffed to handle monthly dialogues with tenants.

The preliminary experiences from the project also show that the Dynamic Heating Accounts concept can motivate tenants in social housing to change their indoor climate to the better. Available indoor climate measurements as well as monthly payments makes it possible for the tenants to follow and evaluate their indoor climate continuously. It is the intension that tenants will perceive indoor climate measurements as more fair, relevant and understandable than the traditional heating accounts.

The comprehensive data from the indoor climate measurements provide tenants as well as building managers with an insight into the indoor climate and energy use in each apartment.

Some building managers underline that data from the measurements can also be used to assess complaints regarding indoor climate quality and to identify apartments with mold risk or moisture damage. These risks can be associated with both faulty installations and bad tenant behavior. It is important to have support from both tenants and building managers in order for the project to have a beneficial effect on both building and tenant health.

The green, yellow and red zones did motivate some tenants to improve the indoor climate in their apartment. The signal that lies in the 'traffic light' colors did however also cause some frustration. It can be a surprise for the tenants to discover that normal everyday use can result in a poor (red zone) indoor climate in their apartment, for example when cooking, burning candles or having guests over. The additional fee for a short time spent in an unacceptable indoor climate (yellow or red zone) is limited. However, it can be a source of irritation that many traditional and valued activities lead to a less acceptable indoor climate classification.

The graphics and wording of the heating accounts were changed from ’green, yellow, red’ to ’green, yellow, orange’ to indicate that e.g. high temperatures were not forbidden or bad per se, it just resulted in a fee, just like in the traditional heating accounts where you pay more, if your radiators are warmer. For the same reason indoor climate values within the yellow or red (now yellow and orange) zones are not called unacceptable but described as values leading to a surcharge.

In Dynamic Heating Accounts, payment differs in form from the traditional heating accounts. Tenants have been used to pay a fixed price monthly on account, and once a year receive either money back or a supplementary bill. In Dynamic Heating Accounts, the monthly payment depends on the indoor climate the previous month, and this could potentially give the tenant a better overview of how they are managing their indoor climate and a more direct incentive to manage it well and save on their heating bill.

Some tenants found it difficult to understand the measurements and calculations that resulted in the monthly heating cost. This has led to many questions from the tenants to the building managers.

The preliminary results show that it is important to continue and possibly intensify the dialogue between tenants and building managers to support a better understanding of the project. Support from the building managers is vital in explaining the Dynamic Heating Accounts concept and answer questions from the tenants. Therefore, it is essential that the building managers are sufficiently prepared and qualified for this task.

From the preliminary results, it can be recommended to:

- Measure the indoor climate in apartments frequently.
- Make the indoor climate visible for the tenants and hereby motivate them to improve their behavior.
- Asses, evaluate and handle complaints on indoor climate in social housing.
- Identify apartments with conditions that in time can cause mold growth or other moisture problems.
- Provide information about indoor climate and building-specific advice on how to improve.

7

SUMMARY OF PRELIMINARY FINDINGS

7 SUMMARY OF PRELIMINARY FINDINGS

> *"The use of 'Dynamic Heating Accounts' has already had an immediate effect. Many of the tenants have a better indoor climate because they maintain a comfortable temperature and remember to ventilate their apartment"*
> *Anton Ahnfelt-Rønne, Project Manager at Domea* [16].

The concept of indoor climate measurements and cloud computing aims at:

- Visualizing the indoor climate in social housing in order to motivate tenants to maintain a comfortable and healthy indoor climate in their apartment.
- Facilitating assessment by building managers of complaints from tenants concerning the building envelope and technical installations.
- Identifying apartments with indoor climate conditions that can lead to mold growth and moisture damage.
- Some tenants and operational staff have shown reluctance to accept the concept. They need to be well informed in order to understand and benefit from the comprehensive data presented as a basis for the monthly billing of heating expenditures.

The project continues until the end of 2021. If the final evaluation of the concept is positive, the ambition is that in the future, social housing sections can choose between the traditional and the possibly improved Dynamic Accounting of Heating.

The future evaluation will comprise the following studies:

- Effect of decreased redistribution;
- Changes in energy use compared to traditional heating accounts;
- Final recommendations in regards to tariff structure;
- Mapping of displacements in the payment distribution in relation to the social profile of tenants;
- Estimate of distributional effects of the margin of error in the measurement data;
- Estimate of the cost level of operation and administration of Dynamic Heating Accounts compared to traditional heating accounts;
- Discussion of other applications of smart indoor climate monitoring, e.g. promoting energy efficiency in the retrofitting of buildings, digital energy labelling, control of ventilation, etc.

8

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How do we motivate tenants to maintain a comfortable and healthy indoor climate without excessive energy consumption in their apartment, and at the same time reduce the risk of humidity-related deterioration of building materials and improve the comfort and health of tenants?

An executive order from the Danish Transport, Construction and Housing Authority has provided an opportunity to develop the concept of 'Dynamic Heating Accounts' and to test a solution that hopefully can improve the indoor climate in social housing as well as reduce the energy consumption in these buildings.

The concept continuously measure temperature, relative humidity, and CO_2 in each apartment. These measurements provide the basis for calculating the individual heating accounts.

The project aims among other things to develop a framework to divide the heating costs between the tenants and a guide for the administration to facilitate the communication between the tenants and the social housing department.

The project is still ongoing. The report covers the principles, methods and framework for measuring and creating the heating accounts. Preliminary experiences and findings are also presented.

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