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A proposal for a new energy labelling procedure for buildings based on measurements instead of calculations

HOFOR
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Preface

EnergyLab Nordhavn – New Urban Energy Infrastructures is an exciting project that will continue until the year of 2019. The project is using Copenhagen’s Nordhavn as a full-scale smart city energy lab, where the main purpose is to research, develop, and demonstrate future energy solutions based on renewable energy. The goal is to identify the most cost-effective smart energy system, which can contribute to solution to the major climate challenges the world is facing.

Budget: The project has a total budget of DKK 143 m (€ 19 m), of this DKK84 m (€ 11 m) funded in two rounds by the Danish Energy Technology Development and Demonstration Programme (EUDP).

Forord


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Executive Summary

In Denmark, it is statutory to determine, and document the quality of buildings’ energy performance based on a theoretical calculation of buildings’ energy consumption. The energy performance of a building is documented according to the energy labelling system. The purpose is to visualize the energy consumption in buildings, and to determine whether the buildings’ performance would benefit from any energy saving measures. However, the theoretical calculation does not take, variations in weather conditions, occupant behaviour, technical installations or poor operation of the technical installations, into account. Because of this a larger deviation between the calculated and the actual energy demand in buildings occurs. The result of this is that often none or incorrect energy saving measures is performed, making it difficult to reach the goals of a CO₂-neutral Denmark in the future.

In this report HOFOR is presenting a new optional energy labelling system, based on realized energy measurements. As HOFOR is mainly working with district heating in this regards, it is chosen to call the energy labelling system a *heat* labelling system.

In addition to remote readings of the buildings’ actual energy consumption more information regarding the condition of the buildings’ construction, and its technical installations, is collected.

A thorough analysis of the data and the buildings’ actual energy performance, will provide valuable information on the efficiency of the buildings’ heating systems, and the potential from optimal operation.

In the new heat labelling system the energy performance of a building will be evaluated based on data as presented below. This evaluation method deviates radically from the theoretical calculation of the mandatory energy labelling system:

- The building’s unit consumption in kWh/m² per year, and development from previous years
- The return temperature from the building’s heating central on a summer and winter day respectively
- The building’s capacity demand during peak load hours (~06-09.00, and ~17-20.00) on a summer and winter day respectively
- The building’s physical condition (incl. building envelope such as insulation conditions etc.), and the condition of the technical installations (system solutions)

Through the work on the new heat labelling system HOFOR wishes to obtain improved benchmarking limits based on actual measurements of the heat consumption, as well as additional illustrations, and visualizations of properties’ energy consumption and performance.

It is believed that by collecting and analysing the right data, as well as implementing the related measures, the district heating system can be utilized in a better way, and an additional capacity is released, in the district heating system.

Based on the work carried out in this deliverable HOFOR recommends to focus on optimizing the design, dimensioning and operation of buildings’ district heating centrals and heating systems. This will bring a lot of energy savings as well as great value for money.

In the future the ambition is to be able to provide customers, consultants, installers and employees at utility companies etc. with the results from the work on the new heat labelling system. The target is to provide an overview of buildings’ heat consumption profiles, both in concern to heat demand and heat efficiency. A more in-depth set of data for use in optimising the operation of the heating central, as well as an indication of the building’s level of flexibility in regards to district heating supply should also be given.

By doing so, the new heat labelling system developed by HOFOR could be a great contributor in reducing the large deviation between the theoretically calculated energy demand, and the actual realized energy consumption in buildings.
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1. Introduction

The current energy labelling system and the building codes are based solely on theoretical values and analysis, and do not reflect the actual energy consumption of the buildings, and the way the customers use the building.

HOFOR has, by monitoring the heat consumption of several thousand buildings, developed a heating labelling system reflecting the real heating consumption of different types, and clusters of buildings. The system is thus a result of the typical buildings’ performance, the weather conditions - and its inhabitants/end-users.

HOFOR is therefore proposing a new energy labelling system based on actual energy consumption of buildings to support and/or replace the more theoretical existing tools and systems.

By comparing the energy labelling systems with the actual energy consumption, it will also be possible to deduct, describe and size the differences between theory and reality, as well as to quantify variations in weather conditions and in end-user behaviour, when developing new building codes.

HOFOR will based on the realized energy consumption of low energy buildings according to A2010 and A2015 as built in Nordhavn illustrate and propose a new energy labelling system.

2. Statutory energy labelling system

It is statutory to energy label buildings in Denmark. The purpose of energy labelling is to visualize the energy consumption to domestic hot water, heating, cooling, and ventilation in buildings, and what opportunities there is to save energy. Energy labelling of buildings is required for newly built buildings, public buildings larger than 250 m², and before sale or rental of buildings. The energy label describes the building’s energy performance, as well as any energy preserving means possible to conduct in the building. An energy label is valid for 10 years.

2.1.1 Buildings are labelled according to their energy usage

When a building is energy-labelled it is inspected, and measured by an energy consultant. On this basis, the energy consultant calculates the building’s energy consumption. The calculation is a measurement of the building’s quality in terms of energy usage vis-à-vis other buildings. It is a theoretical calculation based on standardized values for i.e. occupant behaviour, and therefore it often differs from the
actual energy consumption, which is affected by the weather conditions and the habits of those who live in the building.

Energy labelling works similarly to a consumer informative label. The energy performance certificate, furthermore, provides an overview of any improvements in terms of energy consumption, which would make sense from a financially point of view considering the potential cost savings that could be obtained.

2.1.2 Energy label category A through G

The current energy labelling system was established in 1998, and since then new building regulations, and low-energy houses have emerged. Because of this, it has been necessary to supplement the scale with an additional three subcategories to category A – A2010, A2015 and A2020 reflecting the improved energy consumption in the building regulations of 2010, 2015, and 2020 respectively. See figure 1.

The energy-labelling scale runs from category A2020 to G, where A2020 covers low-energy buildings, which only consume a minimum level of energy, while category G labelled buildings consume the most energy.

2.2 Actual vs. calculated energy consumption

The current energy label is based on a theoretical calculation of a building’s energy consumption. A building’s energy demand includes energy to domestic hot water, heating, cooling and ventilation. It only works as an indicator of the specific building’s quality in relation to energy, as the calculation is based on standardized values for solar gains, heat emitting from occupants, the building’s heat accumulating abilities just to mention a few.

In reality, the actual energy consumption of a building depends on actual conditions in concern to many very specific circumstances i.e. weather, operation of the technical installations, and the quality of the building structure, maintenance and occupant behaviour.
Some of HOFOR’s customers are typically more interested in energy saving measures, and these customers use the HOFOR-developed tool called ForsynOmeter, that monitors the energy consumption in buildings by remote readings of the energy meters. See figure 2.

The tool is an add-on to the current energy labelling system, and provides the end-user with an overview of the customer’s energy consumption and visualizes any changes in the consumption. By monitoring changes in the energy consumption in their buildings, these customers can change the way they use and operate the building accordingly, or investigate other energy preserving means if necessary.
However, the majority of the customers are less aware and not interested in energy saving measures and their user behaviour is therefore affected by this.

It is difficult to predict the occupant behaviour in a building, and because of how much the specific heat demand of a building is impacted by the users it is impossible to accurately estimate the building’s energy consumption in the planning phase. This is the reason why the current energy labelling system, which is based on standardized values as previously mentioned, provides information on the quality of the building’s physics only.

2.3 Energy label categories A2010, A2015 and A2020

The energy label category A for newly built houses sets very strict limits in regards to a building’s yearly energy consumption in kWh per square meter. For the subcategory A2010, the maximum calculated energy demand (to domestic hot water, heating, cooling, and ventilation) allowed in residential buildings is \((52.5 + 1650/A)\) kWh/m\(^2\) per year, where \(A\) is the heated floor area. See figure 3. i.e. a multi-family building with a heated floor area of about 2000 m\(^2\) cannot have an energy demand larger than 53.3 kWh/m\(^2\) per year.

![Figure 3: Energy label category A2010- Source Ingeniøren](image-url)
For category A2015 building, the maximum calculated energy demand allowed is lowered by almost 50% from category A2010 to \((30+1000/A)\) kWh/m\(^2\) per year, where A is the heated floor area. See figure 4. If the building is supplied by district heating, the allowed energy demand is divided with a factor of 0.8, giving a maximum consumption of \((30+1000/A)/0.8\) kWh/m\(^2\) per year. By using the example of the multi-family building with a heated floor area of 2000 m\(^2\) above, the energy demand cannot be larger than 38.1 kWh/m\(^2\) per year to fulfil the requirements of A2015.

For the upcoming energy label category A2020, the limit for energy consumption has been lowered even further and states that the maximum allowed energy consumption of a building is 20 kWh/m\(^2\) per year. See figure 5. The energy label category A2020 sets a frame for energy consumption, requiring that there is a minimum or no demand for heating in a new building. A building is classified according to A2020, when the total demand for supplementary energy for heating and domestic hot water, as well as electrical consumption for ventilation, cooling and pump consumption per squaremeter heated floor area, does not exceed 20 kWh/m\(^2\) per year for housing, and 25 kWh/m\(^2\) per year for companies. For companies, the energy consumption frame includes consumption for lighting. If the building is supplied by district heating,
the maximum allowed energy demand is proposed to be divided by a factor of 0.6 for A2020 buildings, equal to 33.3 kWh/m² per year.

There are special rules for calculating the limit for energy consumption in low-energy buildings supplied by local renewable energy systems, except for areas heated by district heating.

2.3.1 Experience on consumption in newer buildings

Preliminary experiences on the energy consumption in low-energy buildings (A2010) show that there is a risk of larger energy consumption in reality, when compared to the calculated energy consumption. Larger variations in the energy consumption can also be found in similar buildings – depending both on the users’ behaviour, and the operation of the building´s technical installations.

The results on actual energy consumption in comparison to the calculated energy consumption in new buildings, is still limited, and not necessarily representative in all cases. The experience is in particular limited on new multi-family buildings equivalent to category A2015 (and A2020), like in Nordhavn, as a limited number of these buildings actually exist and have valid and stable measured data for their heat consumption. The experience on these types of buildings is therefore based mainly
on professional assessments, and not on measurements. Therefore, it cannot be said with certainty that they are correct.

However, experiences from a sustainable city development project in Malmö in Sweden showed that the actual energy consumption of buildings was as much as 50-70% higher than the specified allowed energy demand in the Swedish building regulations. The Danish building regulations have even stricter requirements in terms of energy demand than the Swedish, and thus the results are expected to be even poorer when evaluating the difference between calculated- and measured energy demand in buildings.

Despite the lack of sufficient measurements on a national scale, HOFOR have been able to make a preliminary assessment on how the actual energy demand differ from the calculated demand in category A2015 buildings. HOFOR made the assessment based on measurements conducted in the Nordhavn area, and in some other new construction areas in Copenhagen.

3. The current heat labelling system of HOFOR

Currently, HOFOR is using a system developed five years ago together with The Danish Agency of Buildings to label the energy performance of their customers. As HOFOR is mainly a district heating company, it was decided to call this system the heat labelling system. The current heat labelling system is optional, and includes additional information on the building and it`s consumption, as well as an indication of how the consumption has changed on a yearly basis. Any renovation initiatives for the building are also included in the current system. The purpose of displaying the heat label like this was to draw greater attention to the energy consumption.

The heat consumption (energy consumption to domestic hot water and heating) is calculated on a yearly basis as an average number given in kWh/m² per year. The energy consumption is adjusted according to degree-days, which is an estimation of how cold it has been, and how much energy is needed for heating alone - in other words the energy demand dependant on the outdoor temperature. Degree-days are used to help compare the customer's energy consumption on a daily basis to a standard year- which is the average number of degree-days per year measured over several years.
3.1 Traffic light system

When the first idea to a heat labelling system in HOFOR emerged, the idea was to make a heat consumption benchmark, based on a model called the traffic light indicator. The colours green, yellow and red respectively would be used to indicate, whether the measured heat consumption was very good, acceptable, or not acceptable, but also whether the consumption was improved, unchanged, or deteriorated from the previous year.

HOFOR had large amounts of accounting data and GIS-data (Geographic Information System) available on buildings in Copenhagen. GIS is a map over all the customers connected to the district heating grid. GIS can also extract information from the Danish building- and housing register (BBR) regarding the building type, size and building year just to mention a few.

By systematically controlling energy consumption in one of the largest building segments in Copenhagen, multi-family houses, the conclusion was that the energy consumption was almost independent of the age of construction. HOFOR’s analyses showed an average yearly heat consumption of approximately 100 kWh/m² in this segment, and therefore the first benchmark was only focussed at 100 ± 30 kWh/m² per year for multi-family buildings. See figure 6 illustrating the reference for the upper- and lower limit of the energy consumption in this segment of buildings in red, yellow and green respectively. To the right, green, yellow and red pointing arrows indicate the change in consumption.

Figure 6: Traffic light tendency indicators – Source: HOFOR
However, like experienced through the energy labelling system, the heat consumption in new and renovated buildings is reduced. Thus, to make *The Traffic Light indicator* more appropriate, HOFOR had to include an additional traffic light signal (light green), which is the reason why *The Traffic Light Indicator* now has four “signals”. It was deemed reasonable that buildings’ heat consumption should be granted the light green “signal” if it was below 70 kWh/m². See figure 7 and 8.

![Figure 7: Current traffic light – source: HOFOR](image)

Before 2015, HOFOR had only registered a few costumers with a heat consumption below 70 kWh/m² for this customer segment (multi-family buildings) despite the fact that the calculated heat consumption in newer buildings was much lower than this according to the building regulations.

In brand new buildings (category A2015), a heat consumption of about 50-60 kWh/m² can now be seen, but very rarely below 38-40 kWh/m² which is the calculated demand for these types of buildings. This indicates that the energy preserving means, such as improved insulation, might have a smaller impact than previously assumed.
3.2 Motivation for a new heat labelling system

Through the continued work with remote metering of energy meters, and benchmarking of buildings in HOFOR, two points of main interest emerged, highlighting the need for a new heat labelling system;

The current heat labelling system of HOFOR, which is used to benchmark all buildings in Copenhagen, is accustomed for only one specific segment of buildings – multi-family buildings. To accurately assess the energy performance of i.e. a small single-family building or a large office building, the heat labelling system must be accustomed to more segments equivalent to the great variety of buildings in Copenhagen.
HOFOR also observed that the operation efficiency of the heating installations was a lot more important than originally assumed and with substantial saving potentials at a small cost. The heating centrals and heating systems in many buildings in Copenhagen are either poorly dimensioned, maintained or operated. Thus, when deciding on efforts to improve a building`s energy consumption it was found that the focus should be shifted from i.e. renovation of buildings’ facades, to more education of the facilitators/caretakers of the district heating substations and heating centrals in the buildings. In order to do so, more information concerning the technical installations in buildings must also be included in the new heat labelling system.

4. The new heat labelling system in EnergyLab Nordhavn

The information that is to be included in the new heat labelling system will mainly be targeted at architects, technical consultants, energy suppliers, installers, and customers. The idea is to use the new heat labelling system to i.e. detect trends in poor energy performance in new buildings with similar designed heating centrals, and thereon to provide this information to a consultant, so that the design and operation of district heating centrals can be improved in the future.

Through the work on the new heat labelling system in deliverable 5.1b (ii) HOFOR evaluated ten buildings. Five new residential buildings in the Nordhavn area (figure 9) and five older residential buildings outside Nordhavn (figure 10), which are more representative of the typical district heating customers in Copenhagen. It was decided to continue working with the building segment we were already very familiar with, multi-family buildings, in the first development phase of the new heat label. This way, all focus could be aimed at including proper information regarding dimensioning, and control of heating centrals-, and systems in buildings.

The intention of evaluating these ten buildings was to use them as indicators of typical/average consumption (unit consumption in kWh/m²) for similar building types in Copenhagen. The size of the investigated buildings varies from 1.000 m² to 14.500 m², and the number of apartments in the different buildings varies between 15 and 180. See typical energy consumption in kWh/m², and calculated energy label in the column for the respective buildings in figure 9 and 10.
Based on a quick evaluation, and comparison of the ten old and new buildings, a very wide spread and not necessarily logical unit consumption is found. I.e. building 3 from 2015 has an energy consumption of 81 kWh/m², while building 8 from around 1920 has an energy consumption of 91 kWh/m² - Almost 100 years separates them in year of construction, but they have approximately the same energy consumption per square meter. Considering all improvements to building standards in the past 100 years...
years this makes no sense. To improve the energy consumption in i.e. these new, well insulated A2015 buildings, it is necessary to understand more about what circumstances that causes different behaviour in the buildings.

4.1 Points of interests for the new heat labelling system

HOFOR have decided on 4 points of interests that is to be included in the new heat labelling system with the purpose of improving the benchmarking of buildings, reduce the energy consumption in buildings, and to provide better recommendations for design and operation to i.e. consultants.

1. Information about consumption pr. square meter in different segments and different building periods (for this case only the segment multi-family houses/residential buildings is investigated).
2. Information about the system temperatures in a heating central (summer and winter)
3. Information about the effect profiles in a hot summer day and a cold winter day. Especially one-hour effect in the peaks from 6-10 o’clock in the morning.
4. Information about the building design and technical installations; the “weighting” of insulation, the accumulation of energy in the construction, and the type of heating installation,

The individual points will be discussed further in the following four sections.

4.1.1 Energy consumption per square meter

The original HOFOR developed heat labelling system is, as previously described, convenient for a larger part of the city because of the huge number of old residential buildings in Copenhagen. The system can however be optimized to include a greater variety of building types. By assessing larger amounts of data, including information from BBR, GIS information and accounting data, it is possible to establish an overview of the variety of building types in relation to construction year, usage (i.e. residential/office) and energy consumption. HOFOR has evaluated these data for some time now, and the next heat labelling system based on unit consumption in kWh/m² is close to completion. The first proposal for the new heat labelling system covers a greater range of construction periods and building types, and an example of benchmarking multi-family houses is presented in figure 11, below.
**Figure 11: Benchmarking intervals for multi-family houses in Copenhagen – Source: HOFOR**

The largest group is without doubt buildings built before 1940 - several thousand district heating supplied buildings are located in this group. In contradiction, there are only a few properties in the group for buildings built after 2015. It is however in this group that HOFOR finds the issue particularly interesting as these are the building types being built today. Therefore the main focus is on the new buildings in Nordhavn in this project.

In the following pages HOFOR has used a residential building in Nordhavn from 2015, with a heating area of around 3.000 m² presented in figure 12, to illustrate how the new heat labelling system will work.
The building’s heat consumption was 155 MWh in 2016 and adjusted according to a normal year the consumption was 167 MWh (the year 2016 was warmer than normal). This is then also the expected and budgeted energy consumption for 2017. The building’s adjusted actual unit consumption for 2016 is 62 kWh/m². This consumption includes energy for domestic hot water, and space heating (there is no heating coil for the ventilation unit, and no cooling). For this building to be granted a light green traffic light signal, the unit consumption has to be below 45 kWh/m².

The heat label of a building will typically be based on measurements of the energy consumption for a two-year period, so that the customer can see the development in their building’s consumption. For this building, the energy consumption in 2015 is not representative as the building’s residents first started moving in at the beginning of February that year. As an expectation of consumption for 2017 (budget 167 MWh), based on what is measured the first 8 months, it seems to be stable around 62-64 kWh/m². The development of the building’s energy consumption is therefore indicated with a horizontal arrow. This is however only temporarily until the development can be correctly evaluated in the beginning of 2018.
4.1.2 System temperatures in a heating central

In the district heating system, one of the most important indicators used to evaluate how well the heating central in a building is working, is the return temperature. If the return temperature from the heating central is low, it indicates that the central heating is functioning correctly as the district heating water is cooled down properly. Meaning that by evaluating the way the return temperature changes, a lot of valuable information can be found.

The return temperature also has a great impact on the capacity of the district heating network, the power consumption for pumping, the heat losses in the network, and the power production in the combined heat- and power plants. In the future, when more combinations of new energy production plants occur such as heat pumps, biomass boilers, and surplus heat from the industry, the return temperature is especially important. In other words, the entire district heating system is dependent on low return temperatures from its customers to work optimally.

The advantages of having a low return temperature differs depending on what time of the day it is. I.e. during the morning energy demand peaks, and during the colder periods of the winter it is very important that the return temperature is as low as possible. To get as much information as possible, it is necessary to evaluate the return temperature during two periods- heating season (winter), and outside heating season (summer).

![Figure 13: Average return temperature from a building during a march in the heating season (winter) - Source: HOFOR](image)

In the example shown in figure 13, the average return temperature is low during the winter period, but it appears to be very fluctuating. The return temperature during the
summer is higher, and even more fluctuating. See figure 14. Thus there is reason to believe that the control valves might be over dimensioned or incorrectly adjusted. This particular building has a floor heating system that might affect the return temperature, however to make a more in-depth analysis of the return temperature in this building, even more information about the technical installations is necessary.

![Figure 14: Average return temperature from a building during a period outside the heating season (summer) – Source: HOFOR](image)

4.1.3 Effect profiles of the individual customer’s heating central

A building’s effect profile shows how the heat demand changes throughout the day. I.e. peak loads in the district heating is normally in the morning when multiple people are using the shower, and the heating is turned on simultaneously. This means an increase in production at the heating plants, and to cover this need for extra energy the peak load boilers are started up. Peak load boilers are based on expensive and polluting fossil fuels, and it is therefore desired to limit the use of these boilers by i.e. moving the peak demand to base load hours. Because of this it is very important for HOFOR to evaluate, and optimize the effect profile of their customers.

In the example shown in figure 15, the capacity need of a costumer increases by about 110% during the morning peak load hours in comparison to the average on a cold winter day.

During the summer period, the building has a capacity demand during morning peak hours of 90 %. This is way too high - in a new building like this one from 2015, where the heating demand is small and the domestic hot water is produced via a storage tank.
The high increase in the capacity demand during morning peak hours is most likely caused by the heat demand for domestic hot water. This indicates that the domestic hot water tank might be too small, or that the regulation valve is too large, or that there is a malfunction in the operation of the domestic hot water circuit.

![Figure 15: Maximum capacity demand in the building in Nordhavn in a winter situation - Source: HOFOR](image)

![Figure 16: Maximum capacity demand in the building in Nordhavn in a summer situation – Source: HOFOR](image)

4.1.4 Building design and technical installations

As previously mentioned, inappropriate design of a building and the operation of a building’s heating central when compared to the building type, construction and intended use of a building might lead to an unnecessary high heat consumption. In order to go for more targeted solutions for a building with i.e. poor cooling efficiency, it is very important to know the relation between the heat consumption and the
buildings physical construction, as well as the design of the heating central and its control possibilities, when developing the new heat label.

Through the work on the new heat labelling system in deliverable 5.1b (ii) information on this matter have been gathered in a sheet as illustrated in figure 17, and separated into three main areas; building envelope, heating central, and heating system.

Figure 17: Detailed building- and technical installation information sheet – Source: HOFOR

4.1.4.1 Building envelope

The construction of the building envelope describes a.o. the heaviness of the construction, the degree of insulation, window area, and whether there are any particularly sensitive commercial areas. This information indicates how sensitive the building might be to draft, and to any changes in the indoor climate. Based on this it is for instance possible to estimate the building’s ability to accumulate heat by looking at the heat demand during base load hours, where the majority of the demand is for the heating system as previously mentioned. I.e. a new, heavy, well-insulated building will have a smaller heating demand than an older, poorly insulated
building as it better accumulates heat and therefore requires a minimal heating supply to maintain a satisfactory thermal environment. This means that it might be possible to utilize the heat accumulation of the building by reducing the heating supply for shorter periods to offer some flexibility to the district heating system during peak demand hours. However, should a new, heavy, well-insulated building have a significantly larger base load demand than similar buildings, or if the energy demand is very fluctuating, then there is reason to believe that something is not working as it should, and further investigations should be carried out.

4.1.4.2 Heating central

In a heating central, it is very important to have information about the type of installations, dimensions of the installations and how these are controlled. I.e. the size of the hot water tank and the dimensions of the control valve and the control of the hot water for use can be critical to the building's total heat consumption. A larger domestic hot water tank can accumulate more heat, which should help reduce peak demand. However, if the control valve of the tank is incorrectly dimensioned or controlled, this capacity is not exploited. Whether the domestic hot water is produced in a tank or via an instantaneous water heater, also influences the heat profile and the possible flexibility.

4.1.4.3 Heating system

The heating systems includes more detailed information about the building`s central heating- and ventilation system. What type of heating system there is in a building can have a great impact on a building`s heating profile as different heating system might be more, or less sensitive to changes in the indoor temperature. I.e. a building partially heated by a ventilation system (water-based after-heating) might experience more abrupt changes in the heating consumption. Whereas some heating systems, such as i.e. floor heating systems, are better at accumulating heat for longer periods and are therefore less sensitive to changes in the indoor environment compared to building heated by radiators.

5. Preliminary result of the new heat labelling system

When all information from the four points of interest have been collected, the final result is collected, and presented in a similar overview as shown in figure 18. By presenting the new heat label this way it is easier to accurately evaluate, and compare all the points of interest against each other for i.e. an installer sent out to optimize the operation of a heating central.
5.1 Flexible operation of the district heating supply in the future?

HOFOR will demonstrate whether it is possible and reasonable to utilize the short term heat storage in buildings to offer flexibility to the district heating system in Copenhagen by reducing the district heating supply to some buildings for shorter periods. Thus, HOFOR is currently working on a weighing of the factor collected in the new heat labelling system to establish what is called a *flexibility indicator* in deliverable 5.2c.

The flexibility indicator is intended to give an indication of different building’s suitability for flexible operation of the heating supply. A building with a high level of flexibility is good at preventing changes in the thermal climate when the heating supply is reduced, or completely turned off, for shorter periods. How good a building is at maintaining a certain comfort level when changes is made to the heating supply is dependent on the heaviness, and level of insulation of the building, as well as how well-functioning the building’s heating central, and -system is. This means that the information gathered through the work on the new heating system can be used not
only to optimize the consumption in buildings, but also to determine a flexibility indicator if correctly weighed. See figure 19.

Figure 19: Points from information sheet weighed, and used to create a flexibility indicator

5.1.1 Evaluation of a specific building`s heat consumption and flexibility potential

To illustrate how the new heat labelling system will be used to evaluate the performance, as well as the level of flexibility of a building we will continue using the new residential building in Nordhavn.

From the section called Building design and technical installations in figure 18 information on the specific building can be found - the building is a residential building from 2015, with a heated floor area of about 3000 m², and consists of 22 apartments. The building is partially heated by radiators in all the common areas (hallways etc.) and by floor heating systems in the apartments. The apartments all have individual ventilation unit with heat recovery.
In short, the evaluation of the specific building in Nordhavn shows that the building is in the green “zone”, by looking at the Customer ideal scale in figure 20. There is however room for improvements as the building’s performance is not in the top of the scale, as buildings from around 2015 is expected to be.

In the Unit consumption and tendency overview it can be seen that the building has a unit consumption of 62 Kwh/m² per year, as previously presented which exceeds the limit for A2015 buildings by 40 %. The building is therefore placed in category 2 (where 1 is the best) in the Performance summary for Unit consumption.

The System temperatures is evaluated as being quite good in the heating season (winter), but the overall evaluation of the return temperature is affected negatively by a very poor cooling effect in the summer. Therefore, the system temperatures of the building is considered to belong in the second best category as seen in the performance summary.

The evaluation of the building’s Effect profile is deemed unacceptable as there is an effect load of 110 % above average during the morning peak hours. During this period, the utility company is under high pressure to maintain an optimal operation of
the production because of the peak demand. A lower capacity variation between base- and peak load hours is therefore beneficial for HOFOR. Because of this the building ends up in the bottom of the scale (category 4) for capacity variation in the performance summary.

The building is believed to have a high level of flexibility, based on the first try of a weighting of the flexibility indicators, and is therefore granted category 2 for the Flexibility indicator in the performance summary. This building is actually a part of a larger test on flexible operation of the heating supply in connection with EnergyLab Nordhavn, and the results from this test will therefore contribute to evaluate whether the preliminary assessment of this building is correct.

The first try of evaluating the customer’s score on the customer ideal scale, based on a weighting of the four, different factors - unit consumption, system temperatures, effect load variation, and flexibility indicator - HOFOR’s conclusion is that the customer scored a 2.2 (where 1 is the best) as shown in figure 20, meaning that it is granted a green traffic light signal.

5.1.1.1 Results and recommendations for this specific building

From this information, different means to i.e. reduce the capacity load variation during the morning peak can be proposed. In this case, a review of whether the control valve of the domestic hot water tank works optimal, is too large or if a fine-tuning is necessary.

The customer meets the requirements of HOFOR Standard Terms of Delivery. From HOFOR’s point of view it is only a matter of further optimization, and we believe that it is possible to achieve this with a small extra effort.

6. Preliminary conclusion

The large deviation between the theoretically calculated energy consumption, and the actual energy demand in buildings leads to incorrect evaluation of buildings` energy performance, making it very difficult to reach the goal of a CO₂-neutral future in Denmark.

Through the work on a new heat energy labelling procedure based on measurements, HOFOR has focused on remote energy meter readings of actual energy demand, as well as correct design, dimensioning and operation of buildings` heating centrals, and –systems.
With this information at hand, the new heat labelling system will be very valuable for HOFOR in the work of properly benchmarking customers as well as to improve the energy consumption of each individual customer for the benefit of the whole district heating system.

HOFOR is therefore recommending to label buildings according to measured energy consumption to focus on the large energy saving potential in correct design, dimensioning, and operation of district heating centrals, and heating systems.

7. Prospective work

The new heat labelling system developed by HOFOR is believed to be of great contribution to the work of reducing the large deviation between the theoretically calculated energy consumption, and the actual energy demand in buildings.

In the upcoming period in the EnergyLab Nordhavn project, HOFOR will continue developing the new heat labelling system by gathering, and assessing more information on the five new residential buildings in Nordhavn, and the five older residential buildings outside Nordhavn.

In the future HOFOR expect to include more new-, and old buildings in the development of the new heat labelling system. Especially the heat demand in the newer buildings will be monitored more thoroughly. On a longer term, the desire is of course to analyse and optimize the energy consumption in all buildings in accordance with the respective building regulations of each building. However, to do so, it is very important to gain more knowledge on what circumstances causes a building to have an ideal-, or less ideal-, energy consumption.

The extra information gathered through the work on the new heat label system will bring, among many other advantages, the opportunity of using “big-data”-methods such as Machine Learning to correlate the large amounts of data, and thereby gain new knowledge on specific heating systems in combination with different building types.

Thus, it will be possible to i.e. identify how a floor heating system operates in relation to a radiator system, both in terms of temperatures, flows and energy consumption.

Machine Learning could also be used to investigate, which features that characterize buildings with high return temperature from the heating system so that targeted measures could be developed to minimize these problems.
In the long term, greater knowledge and increased on-line monitoring of the heating systems, could make it possible to measure the performance and alarm the utility company, when service of the heating central is needed. However, as previously mentioned this would require a very high level of knowledge about the design and operation of the heating system in the building.

HOFOR will continue developing the new heat labelling system, and this work will, among other, include the following tasks:

1. Analyse all the buildings in the Nordhavn area, and evaluate whether the rating and the level of information gathered, is sufficient for providing a good energy performance indicator of the buildings.

2. Analysing of the calculated flexibility indicator of each building, is comparable to the actual flexibility of the specific building.

3. Evaluate whether the information gathered can be used by i.e. consultants and installers to improve the design and operation of the heating systems in buildings.

4. Evaluate whether it is possible to lower the energy consumption, and improve the performance of the heating centrals in all the buildings in the Nordhavn area to unleash extra capacity in the district heating network.

5. Apply all the measured heat meter data in a “machine learning” system to evaluate and analyse the potential for developing a “virtual caretaker” to optimize and automatize the operation of district heating substations.