# MAIN REPORT: BLUEPRINT OF THE SOLUTIONS DEVELOPED

NEEM HUB

Nordic Energy Efficient Mortgage Hub

31 May 2023

PUBLICATION INFORMATION

AUTHORS

COPENHAGEN ECONOMICS
Helge Sigurd Næss-Schmidt
Jonas Bjarke Jensen
Signe Rølmer Vejgaard
Astrid Leth Nielsen
Marco Islam
Simone Ruth Flindhardt

BEHAVIOURAL ADVISORY
Jossi Steen-Knudsen

GREEN DIGITAL FINANCE ALLIANCE
Pietro Visetti
Jannika Aalto
Gerrit Sindermann

EMF-ECBC
Jennifer Johnson
Luca Bertalot

NORDEA
Niklas Rydberg
Jakob Skott Sigtenbjerg

SWEDBANK
Daniel Pergeman
Artin Shams
Jesper Sjöholm

HEMMA
Therese Ruth
Martin Ekenbäck

DTU
Justinas Smertinas
Peder Bacher

CENTER DENMARK
Søren Bernt Lindegaard
Sandijs Vasilevskis

The Nordic Energy Efficient Mortgage Hub aims to scale up lending to energy renovations in the Nordics and will publish a blueprint on how to accomplish this that will be implementable in other regions of Europe and, indeed, the world. In striving to increase energy renovations, the NEEM Hub will help achieve the targets of the European Green Deal and contribute to addressing ambitious national climate targets.

The NEEM Hub is comprised of a long list of institutions from the financial sector, behavioural scientists, mortgage specialists and authorities, and digital technologies communities from across the Nordics, all guided by leading European Economics Consultancy, Copenhagen Economics.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101032653.

NEEM HUB
Nordic Energy Efficient Mortgage Hub

# TABLE OF CONTENTS

NEEM HUB
Nordic Energy Efficient Mortgage Hub

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF BOXES

# PREFACE

The Nordic Energy Efficient Mortgage (NEEM) Hub is a regional part of the Energy Efficient Mortgage Initiative (EEMI) launched by the European Mortgage Federation in 2016. The goal of the EEMI is to assist mortgage lenders in Europe to fund energy renovations and provide green mortgage finance. To tackle the challenges of scaling up green mortgage lending, various solutions have been implemented under this initiative, such as the development of a common green mortgage label, the provision of material data flow for lending institutions, and market research.

However, it has been recognised that certain obstacles are better addressed at the regional level. Additionally, specific opportunities exist in the Nordic market that a regional hub could leverage. Consequently, the European Mortgage Federation (EMF) invited a consortium to establish a Nordic hub for energy-efficient mortgages. The NEEM Hub was launched in June 2021 after receiving support from Horizon 2020.

The NEEM Hub's consortium includes a leading economic consultancy, **Copenhagen Economics (CE)**, which manages the work within the hub. **Behavioural Advisory**, an expert in nudging and behavioural science, is responsible for reaching out to households and running tests. The **Green Digital Finance Alliance**, an expert in transformative digital and financial innovation in green transformation, has partnered with the **Technical University of Denmark** and **Center Denmark**, a data hub for energy data, to use their research on energy efficiency prediction. The **EMF**, the founder of the overall European initiative, works on the regulatory agenda and bridges learnings from the different regional hubs throughout Europe. **Nordea, Swedbank, Hemma,** and **Jyske Bank** are the financial institutions (FIs) that tested the solutions developed in the hub.

In addition, the NEEM Hub has a broad advisory board network with around 40 different institutions, including most major Nordic banks, covering a total of more than €800 billion in the Nordic banking market.[1]

The purpose of the NEEM Hub is to address the "energy efficiency gap" or "information gap," which refers to the fact that many households in the Nordics could benefit financially from energy renovations but remain unaware of them or do not consider them. This is a significant challenge for the Nordic market because even if energy renovations become more attractive (e.g., through taxes and subsidies), households may not consider making them. Therefore, the hub's primary objective is to develop a solution that informs households of their options and potential benefits from energy renovations.

[1] Statista: Leading banks in the Nordic countries in 2021, by total assets.

We chose banks as the driving force to address this information gap for several reasons. First, households trust banks for advice on developing homes and financing them, so banks are expected to be trusted sources of advice for energy renovations. Second, banks have the financial capacity to help realise the renovations. Third, almost all Nordic banks have committed themselves in some form to contribute to transitioning to carbon neutrality and greening the mortgage portfolio would be an obvious place to start.

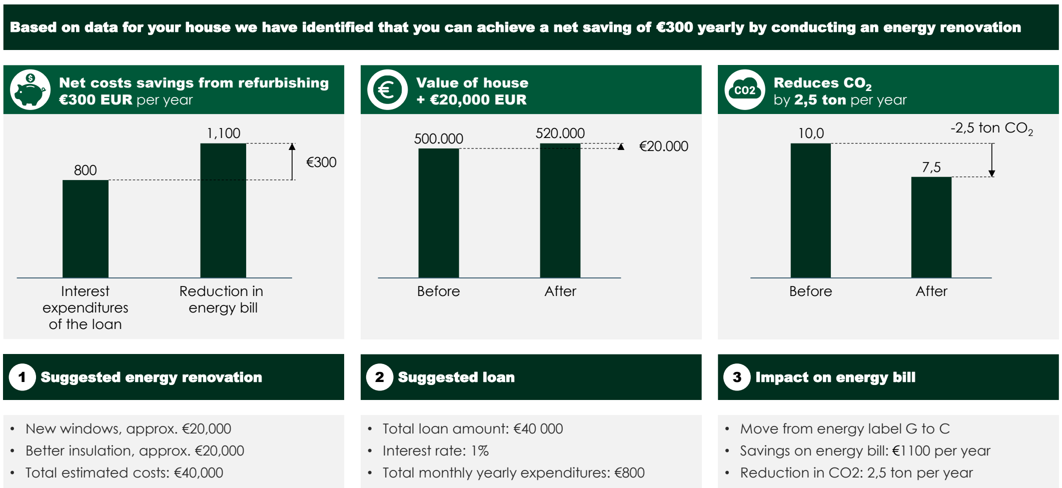
This report will present the value chain for different solutions developed by the NEEM Hub to tackle the information gap.

# EXECUTIVE SUMMARY

**NEEM Core Solution at a glance**
The ultimate purpose of the solution is to identify, reach out to, and incentivise households where energy renovations would be beneficial, not only from a climate perspective but also from a financial perspective, where the savings in energy bills would surpass the costs entailed in such a renovation.

Our vision is to develop a solution that provides the following information to households:

Figure 1
A vision of the NEEM Core Solution




Source: Illustration by Copenhagen Economics

Here is a concrete example of the message conveyed to a given household:
*We have analysed data for your home and found that it could be beneficial for you to make an energy renovation.*

- *We estimate that your household currently has an* energy performance certificate *(EPC) label of G. An energy renovation could increase your energy efficiency to label C.*
- *We estimate that with such a renovation, you could save up to €1,100 per year on your energy bill.*
- *We estimate that the cost of such a renovation would be around €40,000. A loan to finance this would cost you around €800 per year, meaning that you would obtain net savings of €300 per year.*
- *At the same time, we estimate that your home will increase in value by around €20,000.*

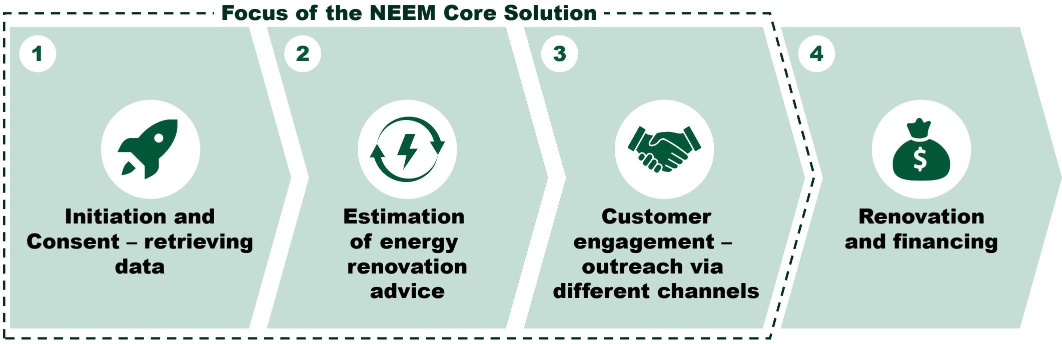
- *Finally, the reduction in energy for a 130 m² house going from label G to C will save around 2.5 tons of $CO_2$ per year, corresponding to driving 20,238 km in a car.*

This information is summarised in a two-page document ('two-pager') that is sent to households, along with a call for action to contact an energy advisor or vendor. An example of the two-pager is provided in Figure 3.

Moreover, we wanted to provide recommendations, without households providing any information themselves. The reason is that once households are asked to enter personal information (e.g., report their energy bill or their number of windows), we would likely lose many potential customers. Also, our purpose is to create a solution where the bank can do some minimum screening of investment opportunities and hence address only households where existing available information suggests there might be a case for investing and providing financial gains for the customer without requiring the customer to provide any information.

In the following, we provide an overview of the value chain of solutions required to produce the two-pager; see also Figure 2.

Figure 2
Value chain of the NEEM Core Solution




Source: Copenhagen Economics

**Data foundation**
We intended to provide tailor-made energy renovation advice to households without requiring them to provide us with their personal information. This presents a significant challenge in terms of data collection and has become a primary focus for our team.

Early in our work, we identified hourly energy consumption data as the key parameter for estimating a house's energy efficiency. While these data should technically be accessible to households, obtaining them directly by asking the owners would likely drive away many households, excluding them from our analysis.

To address this, we established agreements with utility companies that could also provide us with the necessary data (after receiving consent from the households). By combining this with public information on building characteristics (e.g., size of the home and number of floors) and local weather data, we were able to estimate the energy efficiency of the respective households.

**Estimating energy efficiency and renovation needs**
Our next step was to estimate the energy efficiency. If a new EPC label already existed for the household, this step would become unnecessary. However, a majority of households in the Nordics had no labels or only outdated ones. This is particularly true for older buildings, which typically require energy renovation.

To estimate energy efficiency, we developed a model that identifies correlations between energy consumption and weather conditions. The technical details of the model are described in the main report, but the basic premise is that we can identify signs of poor insulation or inadequate wind tightness by observing the impact of temperature and wind on energy consumption.

Once we have estimated energy efficiency for a particular household, we estimate the relevant energy renovation needed. To do this, we use Copenhagen Economics' renovation costs model, which is based on correlations between increasing energy efficiency and renovation costs identified from 130,000 EPC label reports. We validated and modified these estimations, using empirical studies. By using these correlations, we can estimate the likely energy renovation costs for a specific household and identify the renovations that are most likely to provide the largest net savings for the household.

With these estimates in hand, we produced the two-pagers that provide households with the information they need to make informed decisions about energy renovation.

**Reaching out to households and collaboration with vendors**
The FI's outreach strategy is based on the one-stop-shop concept, meaning that households are guided through a customer journey starting with a lack of awareness and ending with completed renovation.

A key instrument when reaching out to households is the two-pager, showing the results of the digital energy screening. However, the purpose of the two-pager, which the household receives when a potential for energy efficiency renovation exists, is not to provide a final answer on whether a renovation is a good idea or not. Rather, the purpose is to identify the cases where the house owner may wish to explore the opportunity and take further action to investigate the potential benefits. The estimates provided on the two-pager serve as a Call To Action (CTA), providing a clear picture of the potential savings that can be achieved through energy efficiency improvements.
Therefore, the focus of the two-pager is primarily on what to do next, e.g., reply to the bank advisor or call an energy advisor. The box promoting this needed action is presented; see Figure 3 and Figure 4.

Figure 3
Example of two-pager (first page with call to action)


Source: Illustration by Behavioural Advisory

Figure 4
Example of two-pager (second page with detailed information)


Source: Illustration by Behavioural Advisory

To create credibility and increase information, the savings potential and the workings of the energy model are presented next. Concretely, we present the yearly savings potential in monetary terms, the $CO_2$ savings potential, the potential increase in energy label, and the estimated increase in house price when renovating.

The FIs have different options for how to introduce digital energy screening to households. One is simply to call a pre-screened sample of households and ask whether they would be interested in a free energy screening estimating the savings potential of their house. Another is to present the offer in a letter. The latter is effective and less resource demanding.

A crucial part of the customer journey is the choice of the collaboration partner. For FIs to become a successful one-stop-shop, efficient collaboration models with third parties such as energy advisors and installers are needed. The two main approaches are to team up with either commercial partners or objective energy advisors. The advantage of choosing a commercial partner is that the solution can be offered and installed by the same partner conducting the energy visit promoted by the two-pager. The advantage of an energy advisor is that more reliable and better solutions may be advised; however, the partner cannot carry out the solution themselves.

**Key learnings**
In the main report, we present the value chain of the solutions in the NEEM Core Solution outlined above and discuss how we have overcome the obstacles encountered in this process. Below, we summarise three key learning points from the process:

- **Agreements with utility companies are crucial**. Obtaining energy consumption data is a game-changer in identifying and guiding households on energy renovations. Without this data, it is challenging to provide tailored advice to a specific household. Ideally, the data come directly from utility companies. While initiatives exist to make public data hubs available in the Nordic countries, GDPR concerns have made it difficult to use the data in a commercial setting like the NEEM Core Solution. Moreover, processing these data involves significant work since industry data often vary from company to company. Therefore, FIs may need to rely on third-party providers.
- **Households are receptive.**[2] We have generally observed a strong appetite for households to have their energy efficiency tested. In a test conducted in Denmark, 39 out of 40 participants agreed to participate, and 32 gave us consent to obtain energy data through their online bank. Almost all of them found it relevant to be contacted with such information.
- **There are uncertainties when choosing a partner to conduct the energy renovation.** Once the two-pager with information on energy renovation is sent, a crucial next step is to introduce the household to someone who can implement the energy renovation. Here, two options exist, both of which may entail additional challenges:

---

[2] Most tests of the NEEM Core Solution was carried out in 2022, where energy prices rose significantly, and was at the top of households concerns and agenda – the timing for testing the NEEM Core Solution was thus very relevant.

1. *Introducing the household to an energy advisor:* They would typically be able to conduct a 360-degree review of the home and consider all relevant energy renovations. However, such visits typically entail costs, and it is not clear who should cover them. If households had to pay, it would likely discourage many from engaging in the renovation. After the energy advisor finishes the visit, the household is left with the challenge of finding a vendor that can conduct the energy renovation.
2. *Introducing the household directly to a commercial vendor:* This implies that the household would engage with someone who can carry out a renovation. However, a commercial vendor would typically not conduct a 360-degree review of the home and is potentially more interested in pushing the renovations that the vendor thinks are most profitable for themselves. This increases the risk that not all relevant renovations or the wrong ones are considered.

Although the NEEM Core Solution is a value chain of interlinked solutions, it should not be seen as a take-it-or-leave-it proposal. Rather, FIs can use parts of the solutions developed. The solutions can be seen as different but internally consistent ideas that can help FIs to expand their lending for energy renovations.

In addition, other obstacles to energy renovation are addressed in the work of the hub, for example, the perception of the high complexity of energy renovation, involving many actors, but where the household only has limited knowledge of the quality of the actors. These solutions are described in separate publications that can be found at NEEMHub.eu.

**Next steps**
The consortium members of the NEEM Hub have spent the past two years developing and testing the above solutions. The results of the NEEM project have confirmed that the NEEM Core Solution is a relevant and effective instrument in engaging FI customers and spurring action in renovating the private household sector. Among FIs, the project has succeeded in strengthening the efforts in the green agenda, and readiness to pursue actions that promote green solutions and green loans is now widespread.

There are several promising ways to build on the results and efforts of the NEEM Hub. In the NEEM Hub, tests were limited to certain geographical areas due to data constraints. By the end of 2023, data coverage will expand by factor 10+, meaning that FIs can target +100,000 households located close to the largest cities in Denmark. A natural next step for the NEEM Hub would be to use the increased data coverage and scale the efforts significantly.

In addition to continuing the work by scaling the efforts, refining and automating the NEEM Core Solution is needed. In the tests so far, the two-pagers have been produced manually. In further tests, this should be automated so that digital energy screenings are quickly and easily produced based on data input.

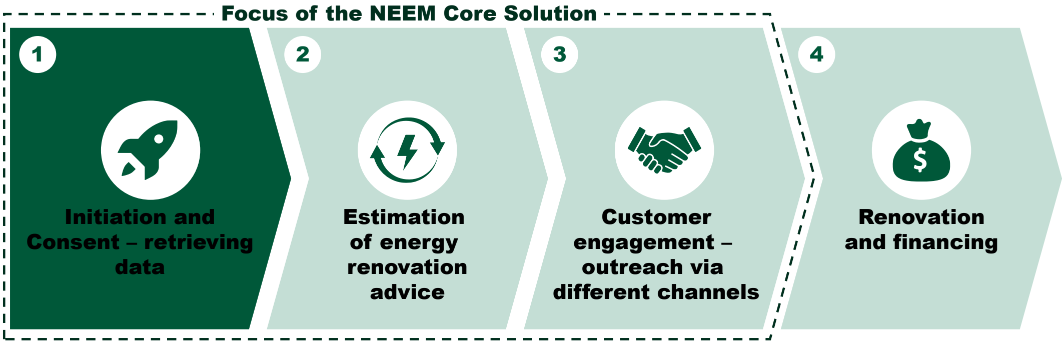
Another interesting topic to explore is optimising outreach channels. Having automatised value chains allows for reaching out to 200 or 2,000 clients. So far customers have been contacted by phone, which is not cost-efficient when reaching out to 2,000 clients. A fruitful next step could be to test alternative outreach approaches such as different versions of digital letters and webinars.

A final promising road to pursue is to assist FI and commercial partners in transferring the business model outside the Nordics. Both FIs and the commercial energy partners have stated their explicit interest in this. As the Nordics in some areas are quite far, e.g., when it comes to availability of data, this road may be the most interesting to pursue in terms of accelerating the green transition.

CHAPTER 1
# DATA FOUNDATION AND PROCESSING

The success of the NEEM Core Solution heavily depends on having data of high quality. Before upscaling the solution, this chapter dives into the data, identifying the key data points, relevant data sources and the most important aspects of the data, see Figure 5. This includes an assessment of the quality of each data type in each Nordic country and the impact on the NEEM Core Solution. Also, current data gaps are considered.

Figure 5
Value chain of the NEEM Core Solution




Source: Copenhagen Economics

This chapter first investigates data quality, potential data gaps and their effects on the NEEM Core Solution. Specifically, we consider energy consumption data, static building data and weather data and discuss their implications. Second, we describe the data-cleaning process as a key element in selecting the relevant households that have all the required data points available. Third, we move on to provide an overview of the primary data preparation principles and steps involved in merging multiple datasets from the different sources outlined above. We focus primarily on the Danish demonstration site, given Denmark's superior data availability and high test participation rate. The dataset preparation for the other Nordic countries is briefly presented. Fourth, we describe the challenges and solutions associated with data preparation for all the demonstration countries. Finally, we give an overview of the interaction process between building the data lake and running the energy efficiency prediction model.

A more elaborate outline of the data-gathering process of the project, including an exhaustive list of data sources, challenges encountered in the creation of the dataset for the energy efficiency prediction model and interaction between the model and data can be found in *Appendix A*.

## 1.1 OVERALL APPROACH: DATA FOUNDATION

The NEEM Core Solution focuses on residential real estate limited to single-family, privately owned homes. To run the NEEM Core Solution, we need a range of different data points that can be categorised into three types:

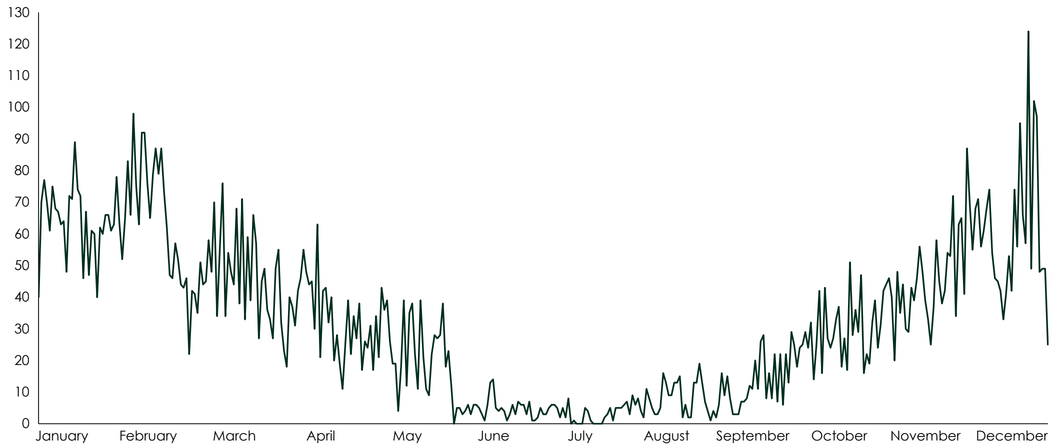
- **Energy consumption data:** The NEEM Core Solution requires energy consumption data used for heating to estimate current energy efficiency. The source for heat consumption can differ from building to building, but the most common sources are district heating and electricity. For this analysis, we therefore disregard alternative heating sources as those could prevent the NEEM-algorithm from predicting the energy efficiency correctly because the consumption data are too infrequent and entail too many uncertainties. If the consumption data's heating source is electricity, it is needed lto learn more about the building's heating system, specifically whether it is a heat pump or a regular electrical heating system.
- **Static building data**: Within this category, the necessary parameters to run the NEEM Core Solution are the number of floors, floor size, total building area, and location (latitude/longitude or postal code, address). The number of square meters is a key datapoint, as the energy performance depends on the building size. Hence it is important to normalise the energy consumption per square meter to facilitate comparability. Additionally, the heating source plays a large role when determining the energy label based on the primary energy factor (PEF) coefficients. The heating source will determine the choice of values for PEFs in each country. Further, the EPC label is a "nice-to-have" data point, against which to compare the estimated EPC label for quality assurance, but it is not essential.
- **Weather data**: As we will describe in Chapter 2, to estimate the energy efficiency of a house, we identify correlations with weather characteristics such as wind, sunshine and temperature. Thus, we need weather data on a granular geographical level.

In the following sections, we go through each type of data and outline how we retrieved the data in each of the three Nordic countries, Denmark, Norway, and Sweden.

## 1.2 HEATING DATA

The NEEM Core Solution is developed and tested with two energy consumption data types: electricity and district heating. Each data source poses challenges. We retrieve the data from private utility companies, either directly or from centralised data hubs. Figure 6 shows the energy consumption over a year for a household using district heating.

Figure 6
Energy consumption over a year for a house using district heating
kWh per day




Source: Center Denmark based on data from TREFOR

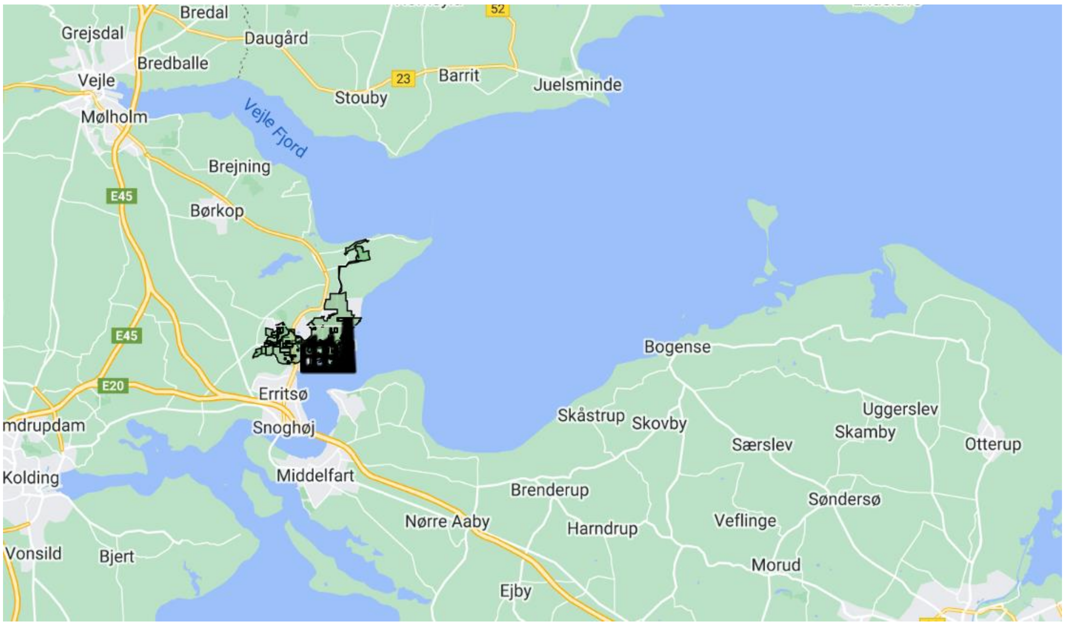
In the following, we describe how we obtained heating data from Denmark, Norway, and Sweden, respectively and tested the NEEM Core Solution.

### 1.2.1 Denmark

In Denmark, we tested the NEEM Core Solution on single-family homes with district heating as the primary method of heating. More than 1.8 million households, corresponding to two-thirds of all Danish households, are connected to district heating. The greatest challenge with district heating is that it is provided by 400 different utility companies spread over the entire country. Moreover, those companies do not have a centrally accessible data hub. To retrieve their data, it was therefore necessary to make bilateral data agreements with each utility company.

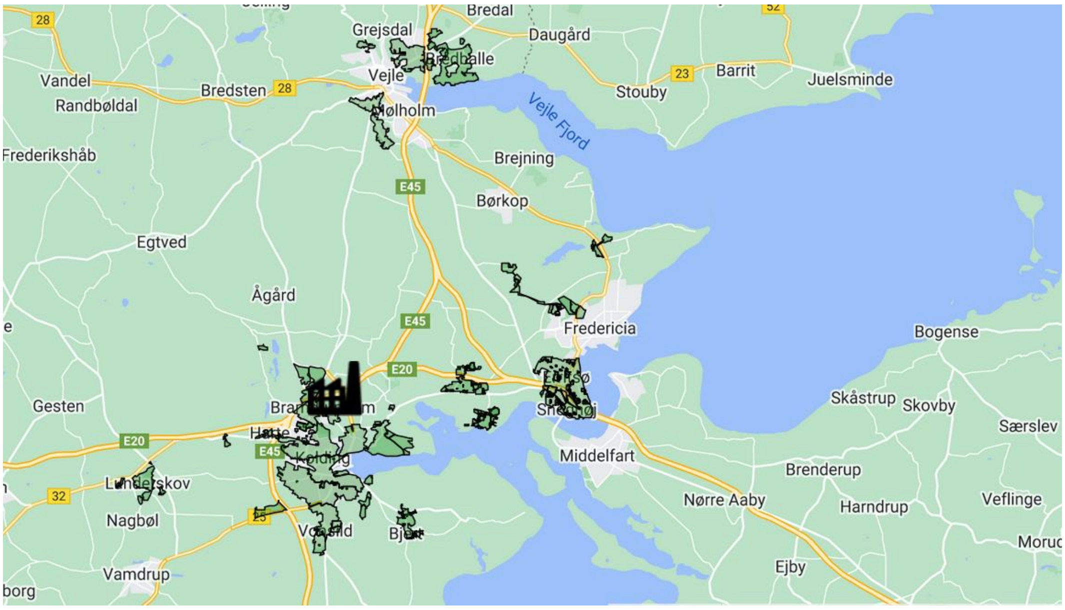
We tested the NEEM Core Solution in Denmark with buildings in the Triangle Region (covering Fredericia, Kolding and Vejle), where most of the sample houses are located in the Fredericia municipality. In that region, Center Denmark has established bilateral agreements with TREFOR Varme and Fredericia Fjernvarme. The two companies are the main district heating providers in the Triangle Region. Figure 7 and Figure 8 below show the aforementioned supply areas of the two utility companies.

Figure 7
Fredericia Fjernvarme's coverage area




Source: DinGeo

Figure 8
TREFOR Varme's coverage area




Source: DinGeo

Providing district heating data for the type of estimation required for the NEEM Core Solution poses a range of challenges: All utility companies provide their data in different formats and with different interfaces, which makes them time-consuming to prepare for our model analysis. For each data source, it is necessary to extract the relevant consumption data into separate files and rename variables to adjust the input layout to the requirements of the NEEM Core Solution. Another challenge was that some households changed their utility provider but the data from their new provider were not available. Such data issues can impair the functionality of the NEEM Core Solution or cause unreliable energy efficiency predictions.

### 1.2.2 Norway

In Norway, households are typically heated by electricity. The NEEM Core Solution was therefore tested with single-family buildings that used electricity as their main heating solution.

In Norway, an advanced metering infrastructure for hourly meter readings, called ElHub, was introduced for all households at the end of 2019. It allows accessing electricity consumption and production data through a centralised data hub. ElHub is a central IT system that supports and streamlines market processes such as electricity sales, move-in/-out, termination of supply, and distribution and aggregation of metering values for all consumption and production in Norway.

A priori, ElHub would appear like a great tool to obtain data for the type of estimation we perform in the NEEM Core Solution. However, to retrieve the meter ID data, it is necessary to first obtain consent for all the meter IDs from ElHub and then approval from all of our NEEM test participants directly via the ElHub portal. Often, we found that the participants were not even aware of the existence of ElHub. In such cases, they would have had to create a profile, register and log into the ElHub portal to allow us to gain access to their data. We deemed this procedure too cumbersome and inefficient and therefore decided against the use of the centralised data hub.

Moving forward, we believe future endeavours in Norway should focus on streamlining that process. We understand that SINTEF, a research institute, is currently exploring the creation of a digital environment with a direct link to ElHub to make the process easier.

Instead of using the meter data from ElHub, we decided to conduct our test in Norway with Elvia, a Norwegian utility company providing electricity. Elvia provided us with the data on the buildings selected for the Norwegian test.

The electricity consumption data from Elvia were of high quality. It was not necessary to join the metering data with publicly available static building data since the metering files already contained building area values. Concerning data formatting, it was necessary to extract consumption data into separate files and rename columns to match the input layout of the NEEM Core Solution.

### 1.2.3 Sweden

For our test in Sweden, we asked households directly whether we could contact their utility company SEOM, which provides electricity, heating, cooling, and waste management services to both private households and businesses in the relevant area (Sollentuna, north of Stockholm).

SEOM allows its customers to download their energy consumption data from its website. This feature allows customers to easily keep track of their energy usage and make more informed decisions about their energy consumption. Moreover, SEOM offered to download the energy consumption data from its website, which has a user-friendly interface. This feature was used in the test of the NEEM Core Solution carried out in Sweden.

## 1.3 STATIC BUILDING DATA

In most cases, we can obtain data related to the buildings publicly from centralised state-owned data sources. Usually, these data can be accessed using open-source API services or are directly downloadable. However, depending on the implementation, it may be necessary to use a digital signature to gain access, which may complicate the process. Table  shows an example of needed static housing data for Denmark.

Table 1
Example of static housing data

| Heat source | Primary energy factor | Construction year | Area | EPC label |
|---|---|---|---|---|
| District heating | 0.85 | 2017 | 168 | A2010 |

Source: Center Denmark based on TREFOR

### 1.3.1 Denmark

Data about all buildings in Denmark are public and can be viewed or downloaded directly from the Danish building registry, Bygnings- og Boligregistret (BBR). The static building data from BBR is available for download using the public API, Denmark's Address Web API (DAWA). However, the relevant information is stored in different tables. We therefore download all tables separately and then merge them to retrieve the necessary data.

In many instances, the building registry data can be outdated. The responsible agency, the Danish Property Assessment Agency, is aware of this problem and is working on improving data quality. For the NEEM Core Solution, the most essential data point is the number of square meters, which is less likely to change over time compared to other variables. Thus, we consider the available data still useful for the NEEM Core Solution.

As an alternative data source to obtain information about the floor size, the number of floors and information about the building's heating system, we can use the EPC report. The EPC report contains all relevant information about a building. It is obtained via a certification process performed by an energy consultant from a certified company. One can search for information on EPC for a particular building and download the EPC report from the Danish Business Authority (Erhvervsstyrelsen) Boligejer website.

The EPC data of all Danish buildings were downloaded using Energistyrelsen's EMO Data-service API. Even though energy label data are optional, these data were used by DTU's data scientists to verify their model predictions and understand whether (and if so, how much) their energy label predictions deviated from the EPC results.

EPC is mandatory and required for the sale and rental of buildings, new buildings and public buildings over 250 $m^2$. An EPC label is valid for ten years unless significant changes that can affect the energy performance are made to the building, Therefore, it is important to verify whether an EPC report is updated recently. Finally, one should be aware that a large amount of the energy label data in Denmark is missing.

### 1.3.2 Norway

The Norwegian Mapping Authority (Kartverket) manages detailed public geographical information for Norway and information about property registry data distribution to users and stakeholders. It allows searches for information about addresses, buildings and properties.

During our testing, it was not necessary to use the Kartverket service since the electricity consumption data included the necessary building area values; no additional data processing was necessary for this data type.

### 1.3.3 Sweden

The Swedish National Board of Housing, Building and Planning (Boverket) is a central government authority that works with issues on how to plan society, buildings and housing. The Swedish Cadastral and Land Registration Authority (Lantmäteriet) is the authority that manages all information on properties in Sweden. Lantmäteriet registers contain up-to-date information on all properties in Sweden.

To access building data in Sweden (e.g., the floor size, the number of rooms, and heating type), one typically needs to have a Swedish personal identity number (personnummer) or a Swedish organisation number (organisationsnummer). This is because building data are personal information protected under the Swedish Personal Data Act (Personuppgiftslagen).

## 1.4 WEATHER DATA

To accurately predict a building's energy performance, the NEEM Core Solution uses weather data from the closest meteorological stations. The NEEM Core Solution and DTU's prediction algorithm require outdoor air temperature, wind speed and global radiation.

Several weather services are available throughout the Nordic region for both historic weather data and forecast data. Since weather data are not GDPR sensitive, meteorological data are often publicly accessible. The data can be found via a file explorer and downloaded and accessed through an open API service. Table  shows an example of the needed weather data for Denmark.

Table 2
Weather data in Denmark, example

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Global radiation ($W/m^2$) | 20.5 | 52.2 | 97.9 | 194.3 | 166.8 | 244.1 | 223.0 | 165.2 | 123.7 | 58.5 | 23.4 | 13.6 |
| Mean wind speed (m/s) | 2.5 | 2.4 | 2.8 | 2.8 | 2.5 | 2.1 | 2.2 | 2.3 | 1.6 | 2.3 | 2.3 | 2.4 |
| Air temperature (Celsius) | 0.4 | -0.4 | 3.7 | 5.0 | 9.9 | 15.9 | 17.6 | 14.9 | 14.1 | 9.2 | 6.2 | 1.5 |

Source: Center Denmark based on Dansk Meteorologisk Institut

In **Denmark**, we retrieved weather parameters from the data portal of the Danish Meteorological Institute (DMI). DMI serves the community with meteorological knowledge and data within Denmark, the Faroe Islands and Greenland with surrounding waters and airspace. For our purposes, the weather data were retrieved using the DMI Open Data API.

In **Sweden**, weather data can be retrieved using the Swedish Meteorological and Hydrological Institute (SMHI) services. SMHI is an expert agency under the Ministry of the Environment. SMHI's observation stations collect large quantities of data, including temperature, precipitation, wind, air pressure, lightning, solar radiation and ozone values. SMHI offers services to build applications using the SMHI Open Data API or downloading files using Explorer to select weather stations and weather parameters.

In **Norway**, weather data were retrieved from the Copernicus data service. Copernicus is a European earth observation program that provides ground-based and satellite-based weather measurements and forecasts. The Copernicus data service contains essentially every possible weather measurement that could be thought of in a fine-grained resolution.

Weather parameters were retrieved using the Copernicus climate programme, and data were downloaded from the Copernicus Climate Change Service (C3S) Climate Data Store (CDS).

If not considered appropriately, weather observations from different data sources may cause inconsistencies in the energy performance model predictions due to different parameter observation methodologies. This concern can also be addressed by using the Copernicus data service, as this contain detailed weather information for all countries. Furthermore, the Copernicus API solution would eliminate the need of creating separate data ingestion pipelines for each Nordic country and its national meteorological institutes.

## 1.5 OVERALL APPROACH: DATASET CREATION AND PROCESSING

The first part of this chapter focused on the data foundation in each test country and the data collection process. We now describe the primary data preparation principles and steps involved in merging multiple datasets from diverse sources. We focus primarily on the Danish demonstration site, given Denmark's superior data availability and a high test participation rate. The dataset preparation for the other Nordic countries is presented briefly. Additionally, we describe the challenges and solutions associated with data preparation for all the demonstration countries.

The first step in the data preparation phase is to ensure the data are formatted correctly so they can feed into DTU's algorithm (the energy efficiency prediction model). To achieve this, the various data from different sources need to be pre-processed accordingly. Some of the data processing tasks include:

- Converting date and time values to ensure appropriate time-series formats.
- Dealing with incorrect and missing values
- Finding the closest weather station based on a building address, coordinates or postal codes.
- Calculating hourly consumption values when the smart metering data were provided as monotonically increasing meter counter positions.
- Normalising address strings from consumption and static building data to properly join and find information about the building area and number of floors.
- Joining data among the different data sources and utility companies.

In the following, we provide a country overview of the dataset creation process.

### 1.5.1 Denmark

Overall, the Danish demonstration site has the best data availability. Nevertheless, we encountered some challenges, primarily when expanding the current data ingestion pipeline. It required communication with the relevant utility companies to ensure their provided data were compatible with the data platform.l

We developed and used Center Denmark's data platform for the tests of the NEEM Core Solution conducted in Denmark. At the onset of the project, some district heating data were already available on the data platform. During the NEEM project, more district heating data from Fredericia Fjernvarme and TREFOR Varme and electricity data in the Triangle area were collected at the data lake and adjusted to the format required for the NEEM Core Solution. Some of the district heating data were available in an hourly resolution and others only in a daily resolution. The DTU algorithm and setup of the dataset had to be adjusted to this. We explain this procedure in more detail in Appendix A.

The next step is to combine the energy consumption data for each household, with the relevant building information data from the Danish building registry, BBR. Thus, the BBR data are placed on the Center Denmark data platform, and the relevant data are combined.

Finally, we combine the energy consumption and building data with the building's geographical coordinates to locate the closest weather station and combine the series with weather data throughout the given year. The weather data are retrieved from the DMI. The dataset is used for several tests of the NEEM Core Solution in Denmark.

Center Denmark has built up a data lake containing energy consumption data for the majority of the Triangle area in Denmark. This can be used for many purposes other than the NEEM Core Solution to support the green transition.

### 1.5.2 Norway

The Norwegian test was conducted with 50 employees from Elvia, a utility company in Norway. To gain access to some of Elvia employees' energy consumption data, the NEEM Hub set up a third-party agreement.

We retrieve the data as a one-time CSV file with tokens to access energy consumption by the employees in recent years. This implies that we do not need to set up a data ingestion pipeline to Center Denmark's data lake. The electricity consumption data from Elvia are of high quality. It is not necessary to join the metering data with publicly available static building data since the metering files already contained building area values.

We did not receive specific IDs or addresses of the Elvia employees but only postal codes. Therefore, we had to map the postal codes to municipality codes. This allowed us to map the weather data to the energy consumption and buildings' characteristics data.

### 1.5.3 Sweden

Since our initial attempts to establish data agreements with several utility companies in Sweden failed, as described in the first part of this chapter, our test conducted with Swedbank is based on test persons downloading their energy consumption data from SEOM. Thus, a single CSV file, containing only the test-related data, is received, obviating the need for establishing a data ingestion pipeline to the Center Denmark data lake. The electricity consumption data require minimal pre-processing. The test persons reported the necessary static building information and heating system type descriptions, implying it was already attached to the energy consumption data and no further data processing was needed.

The weather data were obtained through the services provided by SMHI.

## 1.6 OVERALL APPROACH: INTERACTION BETWEEN DATA AND MODELLING

A close interaction process between the data provider and the model estimations of energy efficiency is needed. In the following, we outline the needed interaction process between Center Denmark and DTU. Additionally, we outline the tools and architecture of the Center Denmark data platform, specifically the version that is used for data hosting throughout the NEEM Core Solution period.

### 1.6.1 The data lake

A centralised repository with all data points needed for the NEEM Core Solution was created in Denmark. To support Denmark's transition to renewable energy sources and facilitate energy flexibility across different sectors and stakeholders, the Center Denmark Data Lake was established as a national-scale energy data foundation. The Data Lake is designed using open-source programs that can be implemented both on-premises and in cloud settings, combining various tools that facilitate big data processing, machine learning (ML), and artificial intelligence (AI).

The data lake can be accessed by using Python, R, Scala, or Bash Shell interpreters, using a web interface that was offering a notebook (Apache Zeppelin).

The data platform has five different data layers:

1. **A data source layer** that refers to data providers such as utility companies.
2. **A data collection/ingestion layer** that pulls the data and loads them onto a dedicated landing repository.
3. **A data storage layer** that represents the central repository, i.e., Center Denmark data lake, where the large volume of energy data is loaded.
4. **A data exploration layer** that allows users to explore the data in the data lake and run their tools and solutions directly in the data platform.
5. **A data consumer layer** that allows authorised external users to fully exploit the data.

### 1.6.2 Definition of input data structure

In developing the NEEM Core Solution, Center Denmark's role was to gather all the relevant data at the data platform described above. DTU's role was to use the data to produce model results on energy efficiency performance. Thus, the interaction between the data provider and model estimator throughout the project was of great importance. This includes selecting the relevant parameters from each data source on the Center Denmark platform.

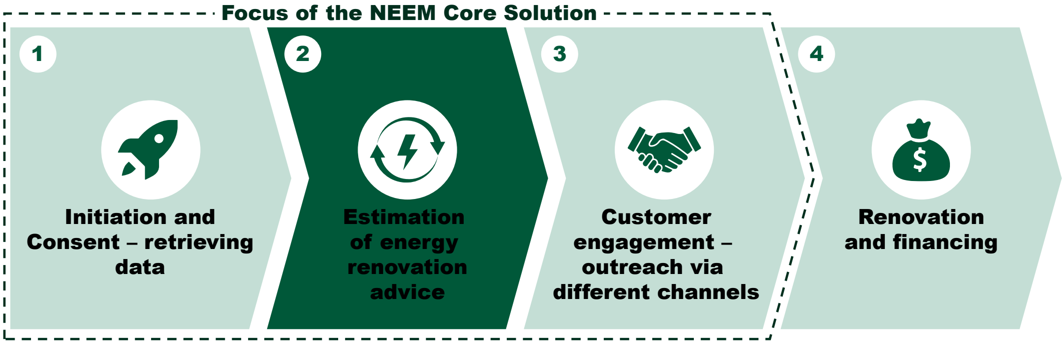
The input data content and layout for the DTU model were developed in multiple steps and refined in an iterative process. The first iteration of sample data contained only a few households and the goal was to align the expectations of the data preparation process concerning the data layout and file structure. Based on this, a separate file for each data source, i.e., consumption, weather and building data was created. Additionally, the consumption data of each household were stored in a separate CSV file, which required changing the dataset from one file to many small files.

CHAPTER 2

# ESTIMATING ENERGY EFFICIENCY AND RENOVATION NEED

Once the data foundation is in place, we can move to the next step in our value chain solutions delivering the NEEM Core Solution; estimating energy efficiency and predicting the renovation need for specific households, i.e., step 2, see Figure 9.

Figure 9
Value chain of the NEEM Core Solution




Source: Copenhagen Economics

For this purpose, we have developed two designated models:

1. **Energy efficiency prediction model**: The first model estimates energy efficiency by identifying correlations between weather and energy use in specific households. This is outlined in Section 2.1 below.
2. **Renovation cost model**: Once the energy efficiency is predicted for the household, we estimate whether an energy renovation would be financially attractive, and if so, to what extent. Furthermore, we estimate the likely impact on housing prices and reduction in carbon emissions. This is outlined in Section 2.2 below.

With these estimates, we have the data we need to produce the two-pager with energy renovation advice and share it with the households, which we describe in detail in Chapter 3.

## 2.1 ENERGY EFFICIENCY PREDICTION MODEL

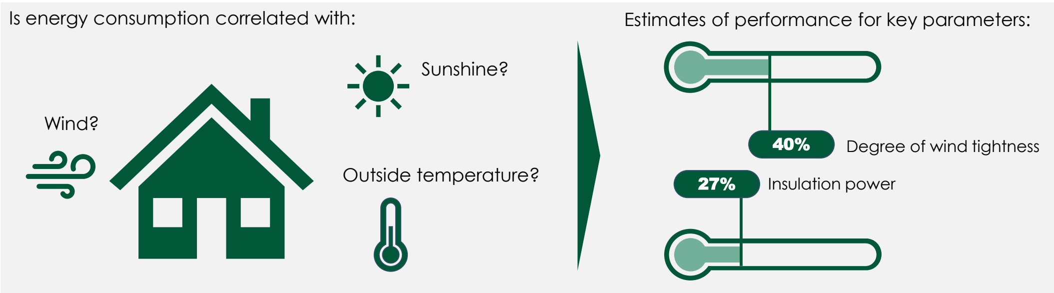
Using the data presented in Chapter 1 in our energy efficiency prediction model, we can now estimate energy efficiency for each house in the different tests.

The model's functioning is described in Appendix B and further documented in Rasmussen et al. (2020): "Method for Scalable and Automated Thermal Building Performance Documentation and Screening."

### 2.1.1 Conceptual outline of the model

The model works by identifying correlations between weather and energy consumption in a household; see Figure 10.

Figure 10
Correlation between weather and energy consumption



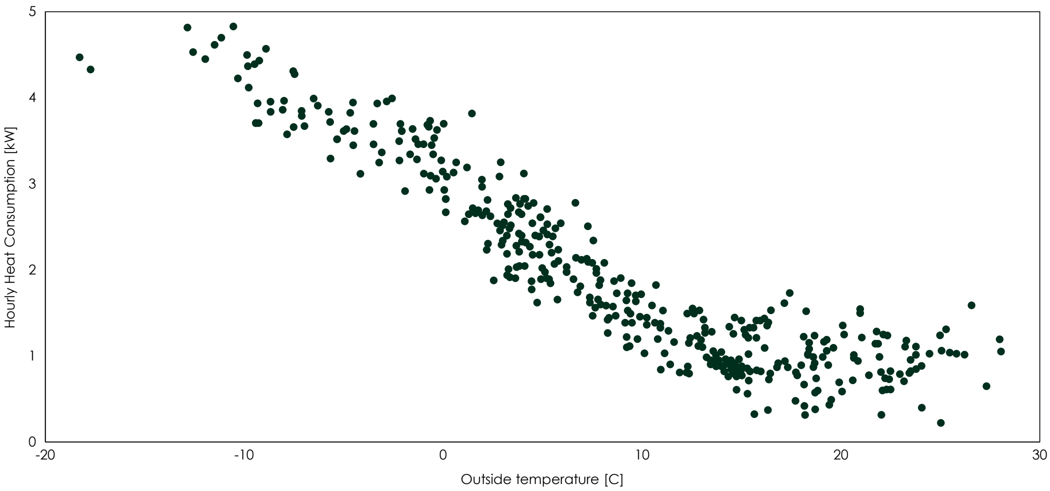

Source: Copenhagen Economics

For example, if the outside temperature drops significantly and the household responds by increasing the indoor temperature sharply, it indicates that the building is poorly insulated. If we notice that the energy consumption drops significantly when the wind blows, it indicates that the building's wind tightness is poor.

Figure 11 illustrates the relation between the heat consumption in a Danish building and the ambient temperature. The fact that all data points form a straight, downward-sloping line illustrates that a strong negative correlation exists between heat consumption and outside temperature. That is, the lower the ambient temperature, the higher the heat consumption. The slope that is formed by the data points represents the heat loss coefficient (HLC) of the building. It describes the rate of heat flow through the buildings' outer material when a temperature difference exists between the indoor and outdoor air. We would expect that the stronger the correlation with the weather, the lower the energy efficiency.

In addition to whether conditions, a household's energy consumption also depends on the owner's behaviour. We capture the causal relation between weather and household behaviour by studying behaviour changes in response to weather changes. This allows us to control for differences (i.e., heterogeneity) in the preferences of room temperature. For example, while one household might prefer a room temperature of 22° Celsius, another household might prefer a temperature of 27° Celsius. Consequently, both households should have different initial energy consumptions, which is important to consider. However, the households' responses to weather changes should not depend on those preferences but only on the energy standard of the house. Thus, we can control for behaviours, focusing only on the actual energy standard of the house.

Figure 11
Heat curve of a typical district-heated house in Denmark




Source: Danish Technical University (DTU)

Based on these correlations and static building data, we can estimate the primary energy demand for each building and use it as input to our renovation cost model. Furthermore, using country-specific definitions for energy performance (see Appendix B), we can convert the metric into an EPC label. This implies that if the model parameters are well estimated (i.e., the effects of weather phenomena on the energy signature are well captured), then the simulation of the buildings' total energy expenditure over a year becomes trivial. With models that can accurately estimate the yearly energy expenditure of a building, the assignment of an EPC label becomes an easy exercise, where we only need to know the correct legislation to determine the EPC label thresholds for each country.

Using correlations with weather data, we can view the energy efficiency prediction model as a type of X-ray that can discover inefficiencies in a building, which in the past could only be identified through a visual, physical inspection by an expert. However, several studies have revealed discrepancies between a building's expected consumption based on its thermal properties and how much energy the building consumes in reality. For example, a 2011 study[3] found that 18 out of 18 (100%) newly built British dwellings had a significantly higher HLC than anticipated in the design when it was assessed by co-heating methods, a technique used to measure the heat loss of buildings. The Danish Energy Agency[4] also found that 23% of the EPC labels issued in 2018 were misclassified, and 21% and 31% were misclassified in 2017 and 2016, respectively.

3 Wingfield et al. (2011): Comparison of Measured Versus Predicted Heat Loss for New Build UK Dwellings.
4 Energistyrelsen (2018): Status for Energimærkningsordning for Bygninger.

A pertinent example of the physical factors influencing energy consumption in the Scandinavian climate is leaky windows. A manual examination of the building may find it difficult to identify a single heavily leaking window, and if it does, it is nearly impossible to determine the additional heat usage of the leak. So, how much does the leak affect the energy performance of the building and how should it affect its EPC label?

### 2.1.2 Transformation to electricity data

Originally, the energy efficiency prediction model was developed to predict energy efficiency, based on heating consumption from district heating with data from utility companies. This makes the model suitable for Danish households, as district heating is a common form of heating in Denmark. However, in Sweden and Norway, electricity-based heating is far more common, with only a minority of households using district heating.

Consequently, we had to adjust the model for our Norwegian and Swedish tests, so it would run with electricity data. This is challenging as electricity consumption captures not only heating but also the supply of home appliances and potentially electric vehicles (EVs).

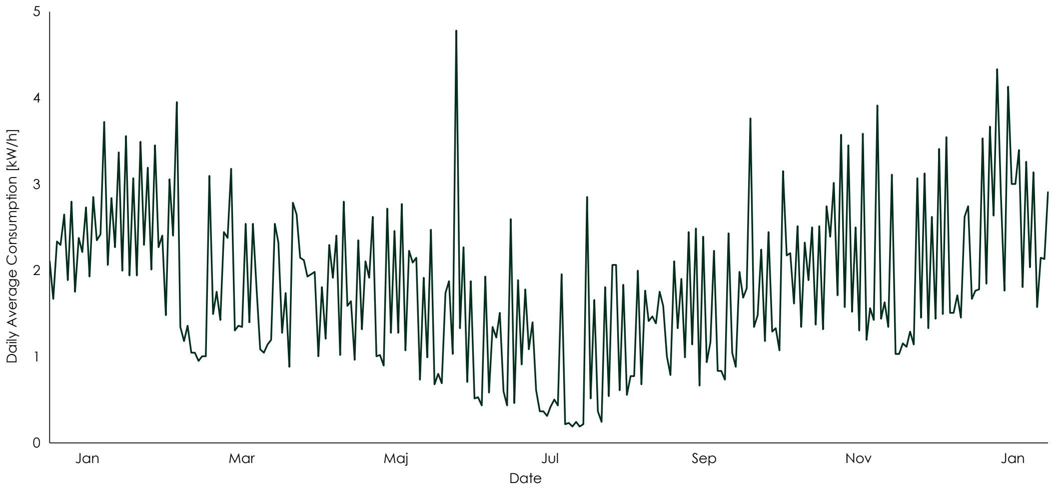
Conceptually, the core functioning of the model should be able to account for this. Recall, we are identifying the level of insulation through weather changes, but neither household appliances nor recharging of EVs should correlate with those changes.

Generally, the combined electricity consumption of typical household appliances such as a fridge, dishwasher, washing machine and television is typically small compared to the electricity that is needed to heat the building through most of the year, at least in the Nordics. However, the charging of EVs can be a significant issue that we need to account for.

Figure 12 depicts observations from a Swedish test carried out by the NEEM Hub. The figure shows the daily average energy consumption of a building heated by electricity paired with an EV charger. As the figure shows, with the addition of an EV, daily energy use starts to vary widely but consistently. By comparison, Figure 13 shows the electricity consumption of a household without an EV. Here the daily fluctuations are considerably lower.

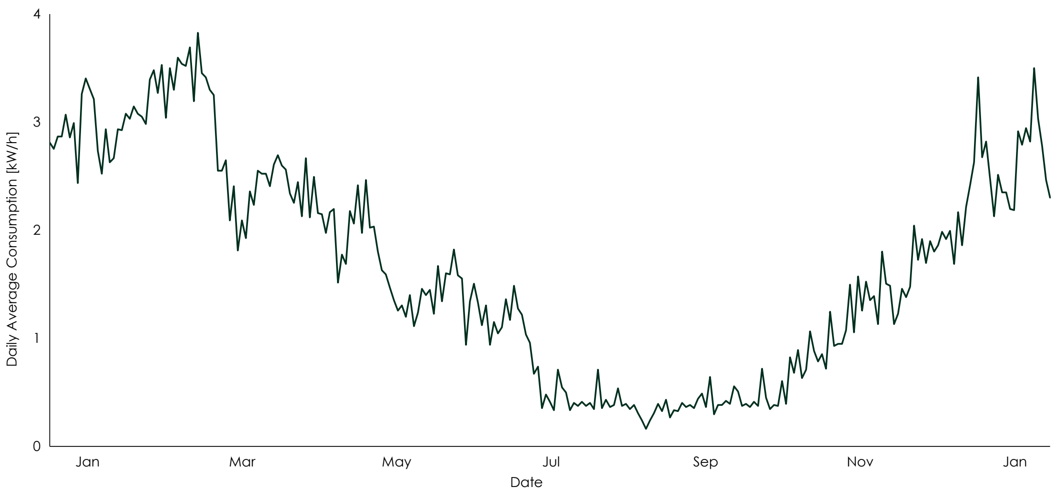
If the data was used in its raw format, our energy efficiency prediction model would be ill-fitted. Therefore, we manually adjust the data. Since EV power consumption is usually highly pronounced, constant, and can generally be spotted by looking at hourly data, households with EVs were not considered. The figure with EV shows a consistent spiky pattern of the EV charging. This can easily be spotted by the human eye, as in this example. However, we do not currently have a non-manual solution for cleaning the data with EVs. Therefore, the buildings with EVs were not considered.

Figure 12
Daily average electricity consumption of a building with an EV over a year




Source: DTU based on the NEEM test in Sweden

Figure 13
Daily average electricity consumption of a building without an EV over a year




Source: DTU based on the NEEM test in Sweden

### 2.1.3 Results from the Danish tests

In this section, we discuss some of the results from the tests conducted in Denmark (together with Nordea and Jyske Bank) that demonstrate the model in action. Results from the remaining tests conducted in Sweden and Norway can be found in Appendix B. Note that the Danish tests are where the DTU model is predicted to fit best.

In the Nordea test, data for 15 households were received. The DTU model produced results for 14 households (as data did not converge for one of the households); see results below. In the Jyske Bank test, data were received for 42 buildings. The DTU model produced results for 41 households (again, data did not converge for one household).

Examining the first two Danish tests results, it is obvious that buildings in the Nordea test have a better energy performance than those in the Jyske Bank test, see Table 3 and Table 4. This is because the Jyske Bank test carried out a pre-selection identifying older buildings with clients in a position to accept a mortgage for the renovation of the building.

Table 3
Jyske Bank test results, Denmark

| Building Number | Old EPC | NEEM - EPC estimated |
|---|---|---|
| 1 | NA | E |
| 2 | NA | F |
| 3 | NA | C |
| 4 | D | E |
| 5 | NA | E |
| 6 | D | C |
| 7 | NA | E |
| 8 | C | D |
| 9 | D | C |
| 10 | NA | D |
| 11 | NA | D |
| 12 | NA | E |
| 13 | NA | E |
| 14 | NA | E |
| 15 | C | D |
| 16 | C | C |
| 17 | NA | E |
| 18 | NA | D |
| 19 | C | C |
| 20 | NA | D |
| 21 | NA | D |
| 22 | NA | D |
| 23 | NA | E |
| 24 | F | D |
| 25 | NA | D |
| 26 | D | D |
| 27 | G | C |
| 28 | F | D |
| 29 | NA | C |
| 30 | NA | D |
| 31 | C | C |
| 32 | C | G |
| 33 | C | D |
| 34 | NA | D |
| 35 | E | D |

| | | |
|---|---|---|
| 36 | D | C |
| 37 | C | D |
| 38 | C | C |
| 39 | D | C |
| 40 | C | D |
| 41 | E | D |

Source: DTU

Table 4
Old and NEEM estimated EPC labels in the Nordea test

| Building Number | Old EPC | NEEM - EPC estimated |
|---|---|---|
| 1 | NA | C |
| 2 | C | C |
| 3 | E | D |
| 4 | NA | C |
| 5 | NA | C |
| 6 | C | D |
| 7 | C | C |
| 8 | NA | D |
| 9 | A2010 | A2010 |
| 10 | NA | D |
| 11 | A2015 | B |
| 12 | A2010 | A2010 |
| 13 | D | D |
| 14 | NA | B |

Source: DTU

In the tests, the EPC label estimates of our model largely coincide with EPC labels determined by experts. For the Nordea test, the new EPC estimates are generally in agreement with the old. The Jyske Bank test shows a larger discrepancy between the conventionally assigned EPC labels and those assigned by the DTU methods. However, the newly estimated EPC labels have neither an optimistic nor a pessimistic trend.

The differences in EPC labels experienced for some households can be variously explained. While energy consumption is a continuous variable, the EPC label system provides discretionary variables. This implies that each label spans a whole consumption range, and the cut-offs are not well-defined. So, if the energy performance of a building is close to a threshold of two EPC levels, small differences in the estimation method may sway the results towards one label or the other. Since the issue date of the EPC label, the building may also have changed, such as being renovated or damaged, and its heating characteristics may have changed, resulting in better or worse performance.

## 2.2 RENOVATION COST MODEL

With the energy efficiency predicted, we can move on to the final step in the model framework, namely, to identify *if* an energy renovation would be beneficial for the household in question, and if so, the extent of such a renovation. For that purpose, we developed the renovation cost model.

Concretely, the model is designed to estimate the costs and benefits of an incremental improvement of the EPC label and analyse whether a renovation investment would be financially attractive. To achieve that, it estimates the energy-saving potentials of multiple renovation scenarios, which facilitates quantifying the costs and benefits of the renovations. In a final step, the model trades off the costs and benefits, determines which renovations would yield net gains and, if multiple scenarios are expected to generate a net gain, identifies for which scenario the profit is maximised.

### 2.2.1 Conceptual description of the model

The renovation cost model consists of three steps, which we will explain in the following; see Figure 14.

Figure 14
Three-step model approach


Source: Copenhagen Economics

*Step 1:* We use the estimations from DTU's model on energy efficiency as inputs to our model and combine them with information about heating costs, obtained from the respective utility company. This is necessary to learn about the current energy efficiency of a household and its current EPC label, to understand the potential for further energy efficiency improvements, and to quantify the cost savings, i.e., the monetary benefits that come along with energy renovation.

Generally, this first step of the analysis reveals that many households have the potential for improvement. We find that more than 95% of the households included in our Danish version of the model have an energy label of C or lower, which suggests that energy renovations can lead to reductions in energy consumption and savings in yearly energy expenses.

However, our model also suggests that some renovations from an EPC label C to a higher one, might not be technically feasible or financially attractive for all households. Because a renovation constitutes an investment, it comes with substantial costs and those costs can differ depending on the energy standard that is in place and the standard that is to be achieved. Thus, it depends on the specific case and is to be more carefully assessed in step 2.

*Step 2:* In the next step, the model compiles the investment costs that a renovation entails. It does so by identifying five different renovation scenarios for a given household. Then, it calculates the expected energy savings and the expected renovation expenses (i.e., the renovation costs) for each scenario. For example, if a house is currently estimated to have the EPC label F, then our model estimates the costs for an efficiency improvement from F to E, from F to D, from F to C, from F to B and from F to A.[5]

The calculated costs represent the total costs for a one-off investment. However, to make the costs comparable to the annual cost savings, they need to be converted to capital costs. Capital costs represent the annual expenses associated with the renovation and thus the minimum return a household expects to receive on the investment. Intuitively, the costs of capital can be described as an annual interest payment to the bank that granted the loan to cover the renovation expenses. For our model, we assume a real interest rate of 2%, which implies that the cost of capital represents 2% of the estimated total renovation costs.[6] We thus compare annual expenses with annual savings, and do not look at so-called "pay-back" time of investment.

*Step 3:* In the final step, the model contrasts the cost of capital and the cost savings (the benefits) for each scenario. This allows us to conduct a cost-benefit analysis similar to one that a profit-maximising household would do. First, we calculate for which households energy renovations are expected to generate a financial gain (i.e. a positive net benefit). Second, we compare the gains and observe for which renovation scenario the gain is highest.

Such an analysis can be quite sensitive to the input parameters that feed into our model (e.g., the energy price or the investment cost assumptions) and it may be naïve to believe that those parameters are constant over time. For that reason, we have decided to take a more conservative approach and only make a renovation recommendation if the estimated profit was sufficiently large. While this shrinks the pool of households for which we can make a recommendation, it reduces the likelihood that our recommendation is negatively affected by changing input parameters.

---

5 For more details on how the model estimates the costs of a renovation based on the identified savings potential, please see Appendix B.

6 The assumed interest rate is thus aligned with current nominal interest rates, which have risen significantly during 2021, from the very low-interest rate environment in most western countries during the 2010:s.

### 2.2.2 Example of how the model works

Table  below provides an overview of the most important model estimations for an example household with an EPC label F. As the currently estimated energy efficiency of the example house is fairly low, the household exhibits substantial potential for improvements and, in turn, the potential for financial gains. We can see that for all five scenarios, the respective renovations are estimated to generate net savings. Nevertheless, we would recommend a renovation from label F to label C because that renovation is expected to maximise the net savings (see row 5).

Table 5
Overview of most important model estimations for five different scenarios: Incremental values moving up one label

| | | F – E | F – D | F – C | F –B | F – A |
|---|---|---|---|---|---|---|
| 1 | Potential energy savings (kWh) | 6,825 | 15,025 | 23,225 | 29,400 | 33,550 |
| 2 | Annual cost savings (DKK) | 4,555 | 10,029 | 15,503 | 19,625 | 22,395 |
| 3 | Total estimated cost of renovation (DKK) | 78,285 | 244,808 | 465,683 | 672,940 | 825,984 |
| 4 | Annual capital costs (2% of total costs) (DKK) | 1,566 | 4,896 | 9,314 | 13,459 | 16,520 |
| 5 | **Net savings (DKK)** | 2,990 | 5,133 | **6,189** | 6,166 | 5,875 |
| 6 | Change in sales price (DKK) | 128,716 | 242,860 | 354,576 | 456,577 | 573,150 |
| 7 | $CO_2$ emission savings (ton/year) | 0,49 | 1,08 | 1,67 | 2,12 | 2,42 |

Note: The renovation scenarios illustrate the effects of a potential energy renovation for an example household from our Danish sample with a current energy label F.
Source: Copenhagen Economics

This example shows that from a financial point of view, it might not be most attractive to improve the energy efficiency of a household to its highest feasible energy standard. The reason is the increasing marginal benefits, which are estimated to fall short of the marginal costs at some point. In other words, while the additional cost savings for an incremental improvement of the EPC label are estimated to exceed the additional expenses for the renovation at the beginning of the EPC ladder (e.g., for an improvement from F to E), this may not be the case for higher standards (e.g., for an improvement from B to A).

### 2.2.3 Additional estimates on $CO_2$ savings and increases in housing prices

In addition to the cost-benefit-analysis of the financial savings potential for households, our renovation cost model provides two additional estimates concerning energy renovations: 1) an estimate of **the $CO_2$ savings** and 2) an estimate of the expected **increase of the housing value**. We communicate both estimates to the households when we reach out to them in stage three of the value chain.

**The $CO_2$ savings** are calculated based on the previously estimated energy savings that follow from the energy renovation in the respective scenario.[7] That is, just

[7] For more details on our assumptions on $CO_2$ emissions that result from district heating, please see the model Appendix B.3.

like the monetary costs and benefits of the renovation, we calculate the $CO_2$ savings for each scenario (see row 7, Table ), but only communicate those estimated in the recommended scenario (provided we make a recommendation to the household). Moreover, we prepare our estimates on $CO_2$ savings such that they become easier to understand for households who are not used to reading and understanding technical language. We convert our initial estimate (measured in tons per year) into an equivalent of kilometres driven in a conventional, fuel-driven car. Note, however, that the $CO_2$ savings per unit of energy saved will become smaller over time as the energy mix becomes greener.

To provide an estimate of how energy renovations affect **the value of a house**, we revert to an analysis conducted by CE in 2015.[8] This analysis reveals that every incremental improvement of the EPC label leads to an increase in the value of the house (see row 6, Table ). However, it also shows that just as for the estimated cost savings, the marginal effect becomes smaller the higher the initial standard of the house. This development appears plausible if one recalls that the housing price increase should reflect the market assessment of the financial gains obtained from energy savings. In other words, the increase in the housing price represents an *alternative* benefit of the renovation, which the household can reap if it chooses to sell the house. Moreover, we know that the marginal increase in house value cannot over time exceed the investment costs associated with improving the energy efficiency of the house. This restriction was used in our estimation of the house price effect in CE (2015).

#### 2.2.4 Model calibration

Before testing our model in a real world setting, we calibrated and adjusted it. To that end, we reached out to a sample of 103 households in Denmark's Triangle area in Jutland that agreed to participate in our "test study".[9]

We observe that for most households the optimal energy standard is the EPC label C. For renovations beyond label C, the capital costs usually exceed the annual savings and therefore render the renovations financially unattractive. However, we also observe that even for renovations to energy standards just below the label C (i.e., for houses with EPC labels D or E), the estimated financial gains are rather small. To account for uncertainties of our model, we do not make recommendations for those houses either, even though our model deems those recommendations profitable. Thus, we end up recommending energy efficiency renovations for houses that currently hold an EPC label of F or lower (approx. 10% of our sample).

Our model is somewhat sensitive to changes in capital costs (interest rates) and changes in energy prices. Recent spikes in energy prices and interest rates are thus projected to affect the results. When energy prices increase, more

---

8 Copenhagen Economics (2015): Do homes with better energy efficiency ratings have higher house prices? Econometric approach.

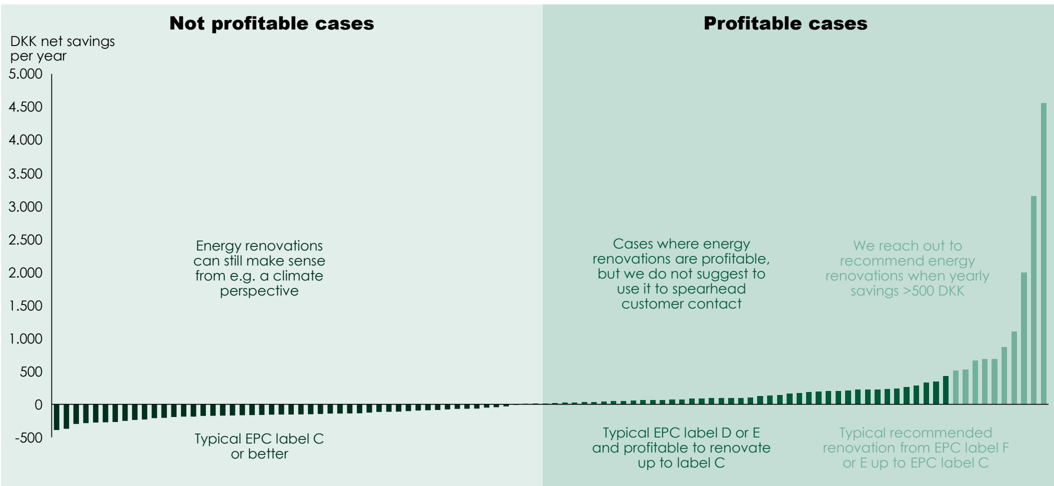
9 The Triangle Region in Denmark consists of seven municipalities on the Danish peninsula of Jutland and the island of Funen: Billund, Fredericia, Haderslev, Kolding, Middelfart, Vejen and Vejle.

renovations will become profitable to conduct. When interest rates increase and capital costs thus increase, fewer renovations will become profitable to conduct.

As illustrated in Figure 15, it is only for a subset of the households for which we make a recommendation, since the estimated net savings are substantial in these cases. These households have a low initial EPC standard, and therefore their renovations up the recommended standard of label C also happen to be the most expensive renovations. That is, we find that the most expensive (profitable) renovations also exhibit the most significant cost savings and therefore provide the greatest potential for financial gains. For the subset of households for which we recommend a renovation, we find total investment costs between DKK 150,000 and DKK 550,000 (corresponds to approximately € 20,000 – 74,000).

After the test, we assured the quality of our model and its results by reaching out to energy experts from the Danish Energy Agency who are responsible for the EPC label system in Denmark. The quality assurance provides the important insight that our estimates on the renovations necessary to improve the energy standard are in line with those of the experts. However, the experts could not provide clear guidelines for the expected costs of the renovations and the research on investment costs on energy renovations provides mixed evidence.[10] We therefore decided to treat the investment costs with caution and take a more conservative approach when making the renovation recommendations.

Figure 15
Yearly net savings for optimal level of energy efficiency
DKK net savings per year




Source: Copenhagen Economics renovation cost model based on CE (2015 and anonymised data on energy consumption and building characteristics for 103 households settled in Fredericia, Denmark.

### 2.2.5 Test results

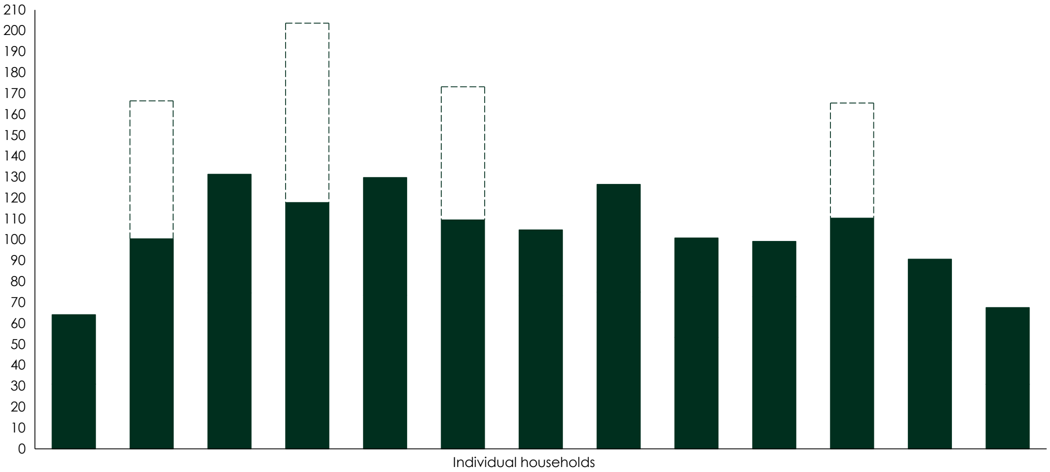
The first test, involving a bank, thorough evaluation, feedback from households, and involvement of an energy advisor was carried out in Denmark with 13

[10] For more details on how we deal with the mixed evidence on investment costs, please see Appendix B.3.

Nordea employees. As for our test, we contacted employees who lived in the Triangle area and asked them whether they were willing to participate.

Our analysis identified four out of 13 households (approximately 30%) with savings potential large enough to make a renovation recommendation, see Figure 16 **Nordea test: Energy efficiency and potential energy savings where renovation was profitable**
. On average, the estimated energy savings amounted to 12,250 kWh per household (or 49,000 kWh in total) per year. Given the energy price charged by the utility company in 2022, this corresponds to potential monetary savings of approximately DKK 8,200 per household per year. All households with significant savings potential had an initial EPC standard of D and the main reason for their heat loss was poor insulation. For all, the optimal target standard was found to be label C. The necessary investments to reach that EPC label were estimated to lie between DKK 250,000 and DKK 550,000. The remaining nine households also showed moderate potential but one that we deemed too small to make a recommendation.

Figure 16
Nordea test: Energy efficiency and potential energy savings where renovation was profitable
kWh/sqm/year by house



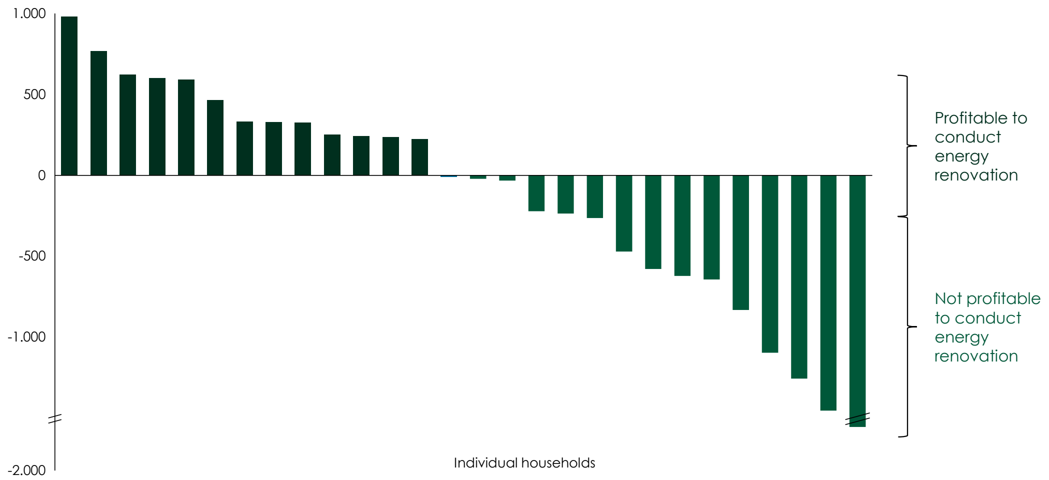

Note: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", and anonymised data on energy consumption and building characteristics for 103 households settled in Fredericia, Denmark.

Our second test in Denmark was conducted with customers from Jyske Bank. Before we ran it, we made some small adjustments to the model, in particular, to its cost assumptions. Other than that, the test was largely similar to the test with the Nordea employees.

We obtained consent from 32 households and performed our analysis with 29 of those; for three households the data quality was too poor. For 13 of the 29 households (approximately 45%), we identified large savings potentials, see Figure 17.

This is considerably more than for our test with Nordea. The reason is that the households included in the Jyske Bank sample were older than in the Nordea sample, which increased the likelihood of savings potential. The identified investment costs for the recommended renovations were between DKK 100,000 and DKK 250,000.

Figure 17
Jyske Bank test: Net savings for each household
DKK per year by house




Note: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", and anonymised data on energy consumption and building characteristics for 103 households settled in Fredericia, Denmark.

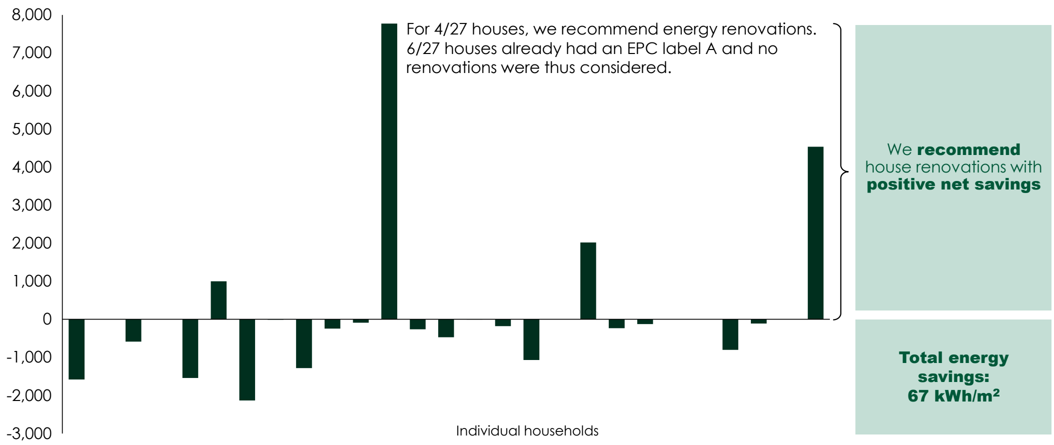
Our third test was performed in Norway. To obtain meaningful results, this forced us to adjust the model once again. First, we adjusted the model concerning the price and cost assumptions. Concretely, in line with the general price level in Norway, we observed that both the energy prices and the renovation costs in Norway are higher than in Denmark.[11] Second, we needed to adjust the model because the houses in our sample were heated with electricity while our model for Denmark was calibrated for district heating. Our assumptions on household behaviour remained unchanged.

We conducted our Norwegian test in collaboration with Elvia, an electricity company servicing large parts of municipalities north of Oslo. As for our test with Nordea, we reached out to employees of Elvia and received consent from 37 households. Out of these, we retrieved robust model results for 29 households (as data did not converge for the remaining eight households) and found that four houses had a renovation potential large enough to make a recommendation.

[11] For details on how we adjust the cost assumptions, please see the Appendix B.3.

Concretely, we recommended energy renovations to four households. If the renovations were carried out, total yearly energy savings would be 67 kWh per square meter, see Figure 18.

Figure 18
Elvia test: Net savings for each house if the optimal energy renovations are conducted
NOK by house



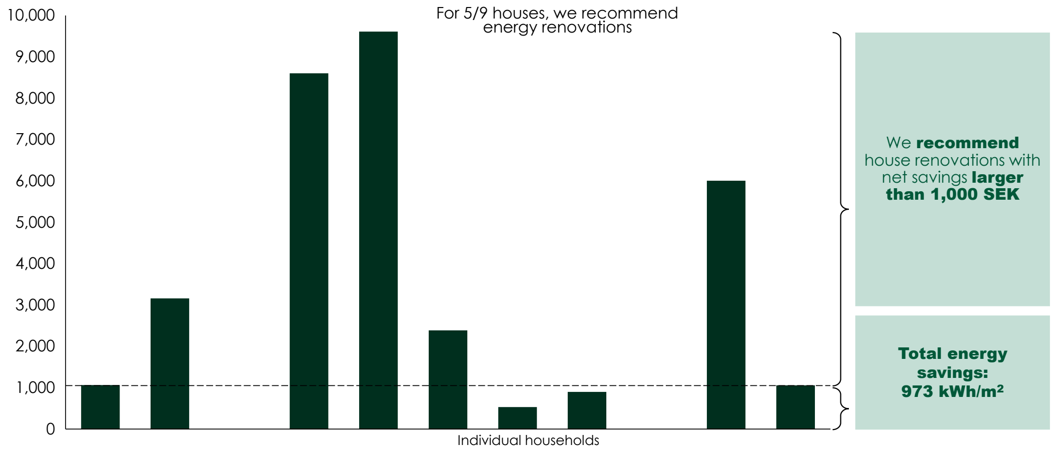

Note: Houses 2, 4, 18, 22, 23 and 26 already had an EPC label A and no renovations were thus considered.
Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Elvia employees settles outside of Oslo.

Our final test was conducted in Sweden in collaboration with Swedbank. We approached households that used SEOM as their electricity provider for heating. The main model assumptions for the Swedish test were similar to those in Norway in that electricity was assumed the to be primary heating source, and not district heating as in Denmark. However, we did adjust our price and cost assumptions to Swedish standards, applied the Swedish building cost index to estimate the development of renovation costs and collected the energy costs from Swedish utility companies.

The Swedish test comprised 12 households from Sollentuna, north of Stockholm. We directly approached these households and asked them to download their consumption data from SEOM's webpage and forward it to us. We also asked them to provide us with some additional information about their houses. While this approach is technically convenient for a sample size of 12 households, large-scale replication might not be advisable. In addition, it might increase attrition if the engagement of the households becomes too large.

Our test results from Sweden revealed that five out of 12 houses had a large renovation potential, see Figure 19. For four households we found a small saving potential (i.e., it is not profitable to conduct an energy renovation). For three households we were not able to estimate the primary energy demand in the DTU model based on the data received (i.e., results did not converge).

Figure 19
Swedbank test: Net savings for each house if the optimal energy renovations are conducted
SEK by house number




Note: The model did not converge for houses 3 and 9, so they have been left out. We do not recommend the renovation of houses 7 and 8, as the annual net savings would be lower than SEK 1,000.

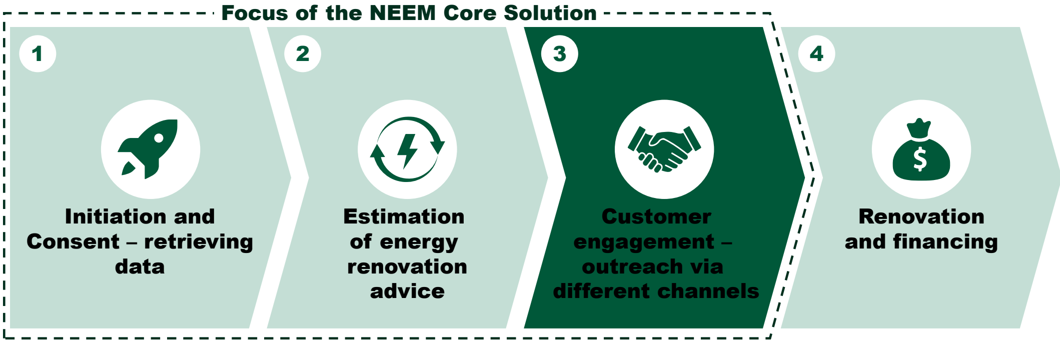
Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Elvia employees settles outside of Oslo.

CHAPTER 3

# HOW TO REACH OUT TO HOUSEHOLDS AND COLLABORATION WITH VENDORS

In the following we present key conclusions on five topics with a strong behavioural component: 1) behavioural guidance on how to reach out to households, 2) building partnerships, 3) test results from six tests in the NEEM Hub 4) feedback from banks on the NEEM Core Solution and 5) what we, the NEEM Hub, have learned from the tests, see Figure 20.

Figure 20
Value chain of the NEEM Core Solution




Source: Copenhagen Economics

## 3.1 HOW TO REACH OUT TO HOUSEHOLDS: BEHAVIOURAL GUIDANCE IS KEY

When FIs reach out to customers, they can use one of two approaches: digital or analogue. Three common digital approaches are attracting customers to a certain landing page, sending direct messages to targeted customers and hosting webinars. Three common analogue approaches are cold-calling customers, bringing up the topic at customer meetings and hosting physical seminars.

The main advantage of the digital approach is the low cost: It is significantly cheaper to send out direct messages to 1,000 clients compared to calling 1,000 clients or bringing energy efficiency up at 1,000 client meetings. However, the main advantage of the analogue approach is the success rate: The chance of commitment is much greater if the message is delivered in person and arguments are presented credibly in the conversation. In addition, the analogue approach may also tighten the relationship to the FI, which is a goal. Today, FIs apply both approaches in various ways.

Several key points should be considered from a behavioural aspect when reaching out to households, as summarised in the following.

**Digital – landing page:** When house owners plan a renovation, the FI's website is not a source that one would naturally seek out in the explorative information search phase. Further, the FI's website competes with the SEO of installers, craftsmen, and manufacturers of energy-efficient solutions. Because of this, the goal is *not* to attract visitors and generate traffic, but that the designated landing page for energy-efficient renovations is informative, engaging and with relevant CTA to external partners. Relevant banking features such as typical loan offers or decision tree journeys should be incorporated. Therefore, retention rather than attraction is key.

**Digital – direct message**: Relevant homeowners can be targeted, and a direct message can be pushed based on available segmentation data. However, it must be perceived as relevant to ensure engagement. Reaction (opening the message) and interaction (clicking the CTA) can be greatly improved by optimising the wording (e.g., playing on loss aversion is generally more effective than promising gains) and timing (following larger life events and changes, i.e., the trigger of, e.g., pension payments or available grants).

**Digital – webinars:** Webinars are generally big generators of leads if the information is perceived as relevant and the providers as trustworthy. A well-structured webinar can attract homeowners at different levels of readiness to buy. An important learning that applies to all efforts is that one of the key identified barriers of homeowners is low transparency and high uncertainty about the quality of providers. Maintaining an advisory role, even as a provider prominently featured at the webinar, is important in building transparency and trust.

**Analogue – calling customers:** Calling customers is time-consuming for advisors and value needs to be balanced for both parties. The advisor has not only to buy in on the purpose of the call but also feel comfortable talking about green renovations and know how to handle follow-up questions and positive responses, that is, know what material to provide to the homeowner and how to easily refer the homeowner to the external partner. Involvement and self-initiatives during the preparation phase can strengthen the advisor's commitment, as well as working together with a team on the action.

**Analogue – customer meetings:** A significant barrier for the advisor is a perceived lack of knowledge on the subject. When an advisor is handed the task of discussing energy renovations at a customer meeting, the lack of connection between their role and the task, amplified by fear of acting as an energy advisor, means they may not be open for the discussion at all. As with calling customers, the advisor must be properly prepared and the limitations of their role must be defined, that is, they are an advisor on financial matters, not energy-efficient renovation; they are only responsible for knowing how to refer to material or external partners for answers, not for knowing the answers themselves. Key behavioural concepts on this matter are touchpoints and hot spots. The advisor should bring up energy renovations when a renovation is already being discussed (touchpoint) or a discussion would be natural (hot spot).

**Analogue – seminars:** Seminars can be a powerful arena for engaging the local community, creating awareness and often shifting the gathered homeowners from an initial search phase to actual decision-making, all within a couple of hours. Gathering homeowners, an impartial expert, one or more suppliers, representatives from the municipality and the FI at a seminar presents an opportunity to overcome multiple barriers at once. Breaking down the silos creates transparency, trustworthiness, and a feeling of exploring the market, advised by impartial experts, while being backed by financing opportunities and municipal support.

**Developing the one-pagers and two-pagers in the NEEM Core Solution**
The starting point of developing the one-pagers and two-pagers is based on the fact that humans are rationally bounded. We like to think of ourselves as rational, but the reality is that we sometimes make decisions based on cognitive biases and heuristics (rules of thumb). This makes us behave systematically and predictably wrong compared to rational standards. In behavioural science, this is explained by dual process theory, in which the system creates systematic errors.

To correct for these, the outreach material is designed to make use of six key principles in behavioural communication:

1. Make it easy (e.g., easy-to-understand language, use of highlighted text)
2. Make it salient (e.g., coloured box and coloured text, large green box)
3. Make it intuitive (e.g., pictograms used to emphasise the meaning of benefits)
4. Make it actionable (e.g., clear step-guide instructions on what to do next)
5. Make it social (e.g., private names are used as much as possible)
6. Make it attractive (e.g., the message highlights the benefit of acting)

In the NEEM Core Solution, a key decision point is receiving the one-pager with the result of the digital energy screening. Here we need the client to accept the CTA and continue the customer journey. Behavioural guidance is pivotal in ensuring that exactly this happens.

To many, the purpose of the one-pagers and two-pagers would be to present the results of the NEEM Core Solution: estimated EPC label, estimated savings if renovating, estimated cost of renovating, and estimated increase in house price if renovating. All of these findings are interesting to the reader. However, it takes space and focus away from the most important purpose of the one-pager: To make the client accept to be contacted by the energy partner. Nothing is more important than having the client continue the customer journey.

Therefore, the CTA is highlighted as soon as possible in a large, salient green box on the two-pager; cf. Figure 21. The first couple of sentences are limited to introductory words explaining that the house belongs to the category 'large savings potential' and that the household can get a free energy inspection. At the top, the address makes the identification clear. At the bottom, a personal signature appears since it creates more trust.

Figure 21
The first page of the two-pager: Large savings potential, Jyske Bank Denmark


Source: Behavioural Advisory

Page two of the two-pager presents arguments credibly documenting the savings potential and the workings of the energy model; cf. Figure 22. At the top, authentic labels and colours are used from the EPC labels to show actual EPC predictions. The benefit of renovating is written so that the savings seem already to be reaped if only one increases the energy label on the mark. Intuitive coding is used to make the key arguments easy to understand. Here we present the yearly savings potential in monetary terms, the $CO_2$ savings potential, the potential increase in energy label and the estimated increase in house price when renovating.

In the middle of the page, the reader is presented with in-depth details of the workings of the model. The purpose is to convince sceptics that the energy model is solid. In the same section, we present a direct proposal to involve the bank advisor, thereby making a clear link between the renovation and the loan offer.

The final words of the two-pager repeat the main message: Reply to this message to accept being contacted by a relevant energy partner.

Figure 22
The second page of the two-pager: Large savings potential, Jyske Bank Denmark


Rosevej 3, 7000 Fredericia
Opført 1936 | 128 m²
Opvarmningsform: Fjernvarme

**Resultat af Energimodel: Stort besparelsespotentiale**

I tilbydes et gratis energitjek da Energimodellen rangerer jeres bolig i kategorien 'stort besparelsespotentiale'.

Energimodellen estimerer, at jeres bolig i dag har energimærke E. Ifølge modellen kan det betale sig for jer at energirenovere boligen, så den får energimærke C.

Gennemføres de rentable tiltag for Rosevej 3 viser Energimodellen, at I kan opnå følgende gevinster:

- Besparelser på varmeregningen på 5.000 kr. årligt.
- Boligens energimærke stiger to trin til C fra det nuværende estimerede mærke E.
- Boligens klimaaftryk reduceres med 0,8 ton CO2 årligt. Det svarer til at køre 6.400 km i bil.
- Boligens estimerede salgspris stiger med 157.000 kr.

**Hvordan fungerer modellen?**

Energimodellens resultater er baseret på beregninger af jeres faktiske energiforbrug i kombination med udendørstemperaturer i boligens geografiske område. Ved at sammenholde varmeforbrug og temperaturudsving, kan modellen estimere kvaliteten af boligens isolering og tæthed. Jo lavere isoleringsniveau og jo lavere tæthed af boligen, jo højere varmetab.

Modellen viser, at 89 % af varmetabet i Rosevej 3 skyldes manglende isolering, mens 11 % skyldes utæthed i klimaskærmen. Tiltag som isolering af vægge, loft og gulv samt tætning af rør og lister forbedrer isoleringsniveauet af boligen, mens tiltag som udskiftning af vinduer og døre forbedrer tætheden af boligen.

For at realisere gevinsterne, anslår modellen en påkrævet investering i omegnen af 200.000 - 300.000 kr. Finansieres investeringen med låntagning fra Jyske Bank, kan besparelserne overstige de årlige udgifter, så I opnår en årlig nettobesparelse. Modellen er baseret på den forventede fjernvarmepris for 2023. Tag en snak med jeres bankrådgiver, hvis I overvejer at lånefinansiere investeringen.

**Hvad skal I gøre nu?**

Næste oplagte skridt er at besvare mailen fra rådgiveren med ordene "Ja tak til gratis energitjek". Gør I det, vil I inden for kort tid blive ringet op af energikonsulent og sammen vil I aftale en dato og et tidspunkt for gennemgangen af jeres bolig. Hvis I ønsker det, kan konsulenten efterfølgende give et tilbud på at løse en eventuel opgave.

Source: Behavioural Advisory

## 3.2 BUILDING PARTNERSHIPS – A TRADE-OFF BETWEEN ADVISORS AND VENDORS

The FIs in the Nordics are at different stages of maturity in terms of fulfilling the aim of becoming a one-stop-shop for energy-efficient renovations. A common factor is the collaboration strategy: partnering with an external provider of energy solutions. FIs do not want the task of de facto becoming an energy advisor. Some banks have tried this strategy, and energy advisors have given workshops and training, but it is not sufficient to overcome the key internal behavioural barrier: Bank advisors do not feel comfortable giving energy advice. The solution is therefore straightforward: a partnership with an external energy consultant.

There are two fruitful solutions for selecting an optimal partner. The FI can team up with a commercial partner, thereby emphasising the value of having a few touchpoints: The client can buy a solution directly from the first contact point, or the FI can team up with an energy advisor, thereby emphasising the value of recommending a trustworthy, neutral partner who cannot sell the solutions but only gives recommendations. As the energy advisor has nothing to sell, the advice might cover and reflect actual needs and optimal solutions. However, whereas the commercial partner is free of charge for the FI, the energy advisor has to be paid by the consumer; cf. Table 6 for detailed pros and cons.

Table 6
Pros and cons of different types of partners

| | PROS | CONS |
|---|---|---|
| Commercial partners | The main advantage of commercial partners is that they can carry out installations themselves. By having a commercial entity visiting the household the household can receive an offer for the task to be solved and does not need to seek further information. In addition, the partnership can be made such that the only economic incentive for the commercial party is driven by potential sales to the household. | A disadvantage of choosing a commercial partner can be that they are motivated by creating profit, hence selling what they have to offer. If the commercial partner cannot fix the problem of the household, it might never be addressed as a topic. Further, if the salespeople visiting the house are too pushy or give a negative impression in another way, this will put the FI in a bad light since they were the ones to recommend them. |
| Energy advisory partners | The main advantage is that the service of having an advisor give objective input is likely perceived as valuable and trustworthy. Such a partnership will put the FI in a good light and help the household make the best decisions on which green solutions to choose. | There are two main disadvantages. The first is the limitation of only giving 'advice' and not a solution that the household can accept. After a visit from the advisor, the household is left with the task of searching the market for craftsmen and engaging with a suitable partner, something which is complex and may never happen. The second is that advisors charge a fee, which the FI has to pay. This is a huge challenge as the pay-off has to be significant to compensate for paying objective advisors for visiting houses. |

Source: Behavioural Advisory

In the NEEM Hub, both commercial partners and advisory partners are represented in the tests. The Danish FI Jyske Bank chose the commercial approach and teamed up with Bodil Energy, a service provider of heat pumps, solar panels, insulation, and home charging. Nordea Sweden (Swedish FI) also chose the commercial approach and teamed up with Hemma, a fintech company, developing an energy advice platform. Nordea Denmark, another Danish FI, chose the advisory approach and teamed up with Ewii, an organisation specialising in conducting energy home visits.

## 3.3 TEST RESULTS FROM SIX TESTS IN THE NEEM HUB – HIGH CONVERSION AND POSITIVE FEEDBACK

In total, the NEEM Hub tested three separate solutions across six individual tests:

- The NEEM Core Solution was tested in four different tests across three countries in the Nordics, in collaboration with Nordea Denmark (Denmark), Jyske Bank (Denmark), Swedbank (Sweden) and Elvia (Norway).
- The Hemma solution was tested in collaboration with Nordea Sweden.
- The Bodil solution was tested in collaboration with Nordea Denmark.

Before showing the results, we briefly present the customer journey for the NEEM Core Solution. Though the customer journey differs across countries, FIs and energy partners, the approach consists of the same main steps. In Figure 23 we present the customer journey in the case of Jyske Bank.

Figure 23
The customer journey of the NEEM Core Solution

| 1 Jyske Bank calls clients | 2 Clients sign consent letter | 3 Clients receive one-pagers | 4 Clients recieve house visit | 5 NEEM collects feedback |
| --- | --- | --- | --- | --- |
| • Jyske Bank calls clients and asks if they would like a free energy screening<br>• Clients are pre-selected based on geography and house and client characteristics | • Jyske Bank sends the consent forms to the clients<br>• Clients log in and sign digitally the consent form | • Clients receive customised one-pagers with estimated energy label and savings potential<br>• Clients with large savings potential are offered a free, physical energy check | • Clients who accept a free house inspection are contacted by Bodil Energy<br>• A partner of Bodil Energy visits the house, gives recommendation and makes an offer if relevant | • NEEM sends questionnaire to  all clients participating in the pilot<br>• Clients who accept are interviewed in depth |

Source: Copenhagen Economics

In Step 1, the NEEM Consortium hosted a kick-off workshop with Jyske Bank. In this workshop, the bank advisors were instructed on how to call customers. The key question to ask was whether the client would like to participate in a free energy screening of their house. The last section of the workshop was scheduled for calls. Within a few hours, the five bank advisors obtained more than 40 customers, all of whom were pre-screened by Jyske Bank.

In Step 2, if the client agreed to participate in the test, the advisor would send a message to the owners of the house. The owners were then to sign a consent form, permitting the retrieval of energy data for their house.

In Step 3, the advisor sent the energy screening result to the client. There were two versions of the one-pager: one for houses with large savings potential and one for houses with small savings potential.

In Step 4, the households with large savings potential could get a free house visit. This required them to answer the message from the financial advisor and then schedule a time for a visit by the energy partner.

In Step 5, the bank advisors sent a questionnaire to all of the clients participating in the test. The questionnaire was constructed by the NEEM consortium. Clients could voluntarily agree to be interviewed in-depth on the phone by NEEM.

**Results of the NEEM Core Solution – four tests in three countries**
The test results and feedback from testing the NEEM Core Solution reveal the great potential for implementing and scaling green initiatives among FIs in the Nordics. Five key results from the test are:

1. The NEEM Core Solution model identifies a significant share of households as having 'high savings potential'. In a non-screened sample, it is 31% of households and in a pre-screened sample, it is 45% of households. Thus, the model can be used to identify substantial numbers of clients it would be relevant to reach out to with green solutions.

2. The client conversion rate, which is the share that accepts the offer from the bank advisor, is high. When clients were called, 96% (46 out of 48 clients) accepted a digital energy screening of their house. This reveals a high interest in uncovering savings potential in residential housing.

3. Among households with large savings potential offered a free house inspection, 71% act and trigger the next step in the customer journey. This reflects that the one-pager succeeds in overcoming the largest behavioural barrier of reluctance to act. The figure of 74% is a combined figure across the two tests for Nordea Denmark and Jyske Bank. The corresponding figures for the two FIs are 50% and 77%, respectively.

4. In total, 74% of the clients participating in the NEEM Core Solution test thought the overall experience from the FI initiative was 'good' or 'very good'. Further, 79% of all clients thought it was positive if FIs engaged in energy initiatives. Both figures reveal significant support for specific initiatives and similar green initiatives in the future.

5. Clients who talked to the energy partner, Bodil Energy, and received a house visit from the collaborators of Bodil Energy were more likely to give negative feedback and report specific negative experiences. The main reasons were 1) inconsistency between the results of the energy model and the advice from Bodil Energy and 2) negative impression of the collaborators conducting the house visit.

**Results of the Hemma Solution**
The Hemma Solution was well received among the Nordea customers and the Nordea staff, from both conversion and customer satisfaction perspectives. Several concrete improvement areas and aspects to consider for further development were also collected.

In terms of conversion, >25% of all households testing the service selected an energy renovation activity and booked an onsite visit with at least one installer. This is a considerably high conversion for an online service, especially considering the size of investment for these types of activities. Most households in the test went for solar panel installations.

In terms of customer satisfaction, 46% of the participants had a positive (SCore 4-5) overall impression of the service as a whole whereas only 14% had a negative (SCore 1-2) impression. Customers appreciated the low effort, cost indications and access to suppliers that the overall service concept offered. In total, 61% of participants had a positive (SCore 4-5) overall impression of the Hemma flow whereas only 18% had a negative (SCore 1-2) impression. The flow is seen as a smooth and effortless way to get suggestions and acts as a push for action.

The two main areas for improvement include the experience flow in the platform and aspects of the external partner, i.e., the suppliers of energy solutions. Customer feedback on possible improvements to the flow of the digital platform included making the potential cost savings and payback time more visible. Several customers had not noticed. Further feedback involved clarifying which data are general (based, for example, on a geographical area or type/age of house) and which are property specific and being able to add actual consumption and energy prices to make it even more precise and give more value as opposed to being just sales. Another feedback point was improving the navigation flow as a few customers felt it was cumbersome on mobile devices. The most important feedback on suppliers was that they were often too quick to contact.

The market test shows that the concept of the Hemma Solution works. Banks and households need and expect this type of service. Banks are expected to play a role and have the authority to speak to households in these matters from the position of advisors in household economy and property-related matters. This is further amplified by aspects such as soaring energy prices, general awareness, and willingness to invest in energy efficiency among households, and the increasingly evident impact energy performance has on property value.

Hemma believes that the new and evolving regulations call for greater transparency and disclosure of ESG-related data. Several Swedish banks have communicated concrete targets for reducing financed emissions of their mortgage portfolio by 2030. Hemma sees a demand and an expectation for this type of service in the future.

**Results of the Bodil Solution**

In the test conducted in collaboration with Nordea Denmark and Bodil Energi, Nordea employees were trained to bring up solar panels at customer meetings. This is a difficult challenge to solve since it requires stepping out of the comfort zone and proposing green solutions face to face. The results show that only 10% of the bank advisors proposed solar panels in practice, which is a relatively low share. However, those who did were extremely successful, and client feedback from interviews shows that the bank is rated positively for its initiative in the green agenda.

Feedback from customers collected by NEEM reveals that customers value the smooth process, fair price and reliable advice from Bodil. When Bodil receives criticism, it is often due to high expectations. A takeaway is therefore to manage expectations better. Although the Bodil-Nordea solution delivers high client care compared to other suppliers, it is not possible to predict all types of likely challenges at the first house inspection.

Clients positively perceived that Nordea and Bodil have a formal partnership. The partnership creates trust in Bodil and increases the belief that the client will get a loan to finance the solution. Below are some quotes supporting this finding. A key finding is that Nordea receives big kudos from all interviewed customers for promoting green solutions. The customers commonly encourage Nordea to engage in similar activities in the future.

In addition to the primary test, the NEEM Hub has contributed behavioural advice and solutions to two tests run by Nordea in collaboration with Bodil.

In the first test, the digital test promoting heat pumps, Nordea Denmark wrote a combination of direct messages with a link to the website and direct messages with invitations to a webinar. The approach yielded impressive conversions: Among 100 positive reactions to digital letters, 97% received a report, 40% had their house inspected and 13% carried out a refurbishment. The numbers were counted three months after initiating, which means that some may act in the future, as refurbishments usually take time from thought to action.

In the second test, the analogue test promoting heat pumps, Nordea Denmark called customers and asked if they would be interested in being contacted by Bodil Energy. Highly interesting, this approach was only slightly more efficient compared to the digital in terms of conversion: Among 100 calls with positive feedback, 94% received a report, 30% had a site visit and 14% decided to renovate. These impressive figures prove how receptive clients are and how much value the FI can create with a well-functioning partnership.

## 3.4 FEEDBACK FROM BANKS ON THE NEEM CORE SOLUTION – THE NEEM HUB PAVES THE WAY FORWARD

The overall perception of the NEEM Hub collaboration and the NEEM Core Solution was highly positive. FIs describe the approach as a good, pragmatic solution to tackle some of the barriers for homeowners to transition to a greener state. They highlight the value of addressing the attention gap since most homeowners do not think about the energy savings potential and creating clear and easy decision points.

The technical aspects of the NEEM Core Solution are praised, and the model is characterised as an innovative solution as it, for instance, includes weather data in its estimations. This allows it to estimate energy performance precisely for the individual building, which is a contrast to standard generic advice to the customer.

The feedback from the banks emphasised the importance of a behavioural approach when internally addressing advisors and externally addressing clients. In particular, making the behavioural barriers tangible and understandable is highlighted as a valuable contribution of the NEEM Hub.

**Experienced challenges and appropriate solutions**
Five key challenges were faced by the FIs.

First, it was a challenge that initiatives such as the NEEM Core Solution require cross-unit alignment. Cross-unit alignment is a prerequisite for the implementation, which is a challenge since different units within the bank have different priorities and objectives. This often creates ambiguity in the role played by the FIs within the ecosystem of the collaboration model.

Second, there was a lack of priority on lifting the green agenda and a lack of ownership and connection to the strategic agenda in the business strategy. Many FIs are still somewhat immature in this field internally to fully explore the potential of the NEEM Hub and other green solutions.

Third, data approaches such as the NEEM Core Solution were challenging due to GDPR restrictions. The FIs need a setup where bottlenecks are efficiently removed before initiating a process that will not work in practice. Concerning this, an internal barrier is typically the availability of resources in IT development. When testing the NEEM Core Solution, FIs sometimes had to develop a consent document and ask participants to fill out the document to gather energy data for their households.

Fourth, it was a challenge for some headquarters to assess the financial costs versus the benefits of pursuing the green agenda in the NEEM project and similar approaches. They doubted whether the time spent by employees (costs) to test the NEEM Core Solution would lead to sufficiently increased sales and closer relationships with the homeowners.

Fifth and finally, how the homeowners would react to the bank contacting them regarding energy renovations was a concern. Most advisors saw the potential in getting closer to the homeowners with the NEEM Core Solution. The main barrier was the advisors' concern about becoming energy advisors to the homeowners instead of economic and financial advisors.

In terms of solutions, GDPR and consent are topics to be highly prioritised. It is pivotal that consent is built into the process in an easy or even automatic way, so it does not become a key barrier. In the Hemma Solution, the customer gave consent when applying the solution as an initial step. Seconds later, the customer had the result. This is exemplary, but consent can also be automatically given from previous processes, making it unnecessary in scaled versions of green initiatives.

Further, the FIs should establish clear goals and objectives for the implementation process and ensure that all units are aligned with these goals. Internal ownership and cross-unit collaboration are a must. For this process, a distinct collaboration between business-oriented employees and product owners is crucial.

Finally, partnerships with energy consultants are needed. For the advisor, it is crucial to be able to point to an external party so that they do not become responsible for giving energy advice. Once the partnership is founded, the advisors enjoy contacting clients and their outreach is well received in virtually all cases.

**Learnings and next steps**
The FIs' most important learning from participating in the NEEM Hub is described as insights into the importance and types of barriers to energy efficiency improvements. The learning curve has been steep and there have been many challenges along the way: technical, legal, and internal governance. Learning from the collaboration with current and potential future partners such as Hemma, Bodil Energy, and Watts has helped the FIs pave the way for further collaboration to resolve the challenges in promoting green solutions.

The FIs exit the NEEM Hub collaboration with concrete and ambitious tasks as the next steps in their green agenda. FIs aim to expand the product offering to cover more green products incentivising the customers (e.g., with discounts), further build the data foundation for both reporting and customer insights, test scalable solutions to provide insights to homeowners and partner up in relevant areas to complement data or products to tackle the homeowners' barriers.

As one FI put it:

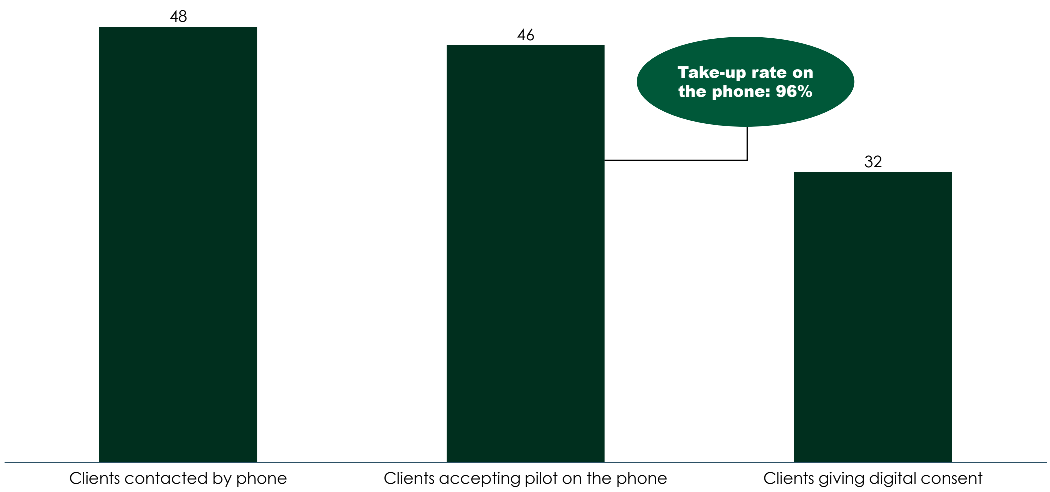
"We want to be relevant for our customers when it comes to energy renovations. Data-driven tools like NEEM core solutions can help us with this in an efficient way. (…) It is time-consuming and often difficult for private homeowners to know if it is worth the cost to renovate their home. The NEEM core solution helps them to get an idea if there are potential cost savings from renovating. (…) With the good response we got from the homeowners in the test, we expect to do more like this going forward."

## 3.5 WHAT WE, THE NEEM HUB, HAVE LEARNED FROM THE TESTS

There are five key takeaways from the six tests.

**Households are receptive!**
We generally observed a strong appetite for households to have their energy efficiency tested. In a test conducted in Denmark, 46 out of 48 participants agreed to participate, and 32 gave us consent to obtain energy data through their online bank. This corresponds to a 96% take-up rate on the phone; cf. Figure **24**. Hence, almost all clients find it relevant to be contacted with such information.

Figure 24
Clients accepting test and later giving consent
Number of persons




Source: Behavioural Advisory

**Vital for FIs to build partnerships**
For FIs to become a successful one-stop-shop efficient collaboration model with third parties, e.g., energy advisors and installers, are needed.

Partnering with a company that can pick up leads and carry out energy renovations is on most FIs' agendas. The behavioural aspect of this collaboration model is that the customer journey should be behaviourally optimised and experienced as smooth and comfortable. The FI should generate the most promising leads for the external partner and the external partner should fruitfully promote the loan terms when giving the offer. The details of who does what, when and how across FI and external parties are crucial for obtaining the best results.

The employees of the FI, in particular the banks' advisors, are also a key target group in the NEEM project. Talking about refurbishments is not core material for a bank advisor. Typically, bank advisors quickly feel out of their comfort zone when bringing heat pumps into a conversation about interest rates. The result is that refurbishments and the green agenda are not brought up at all.

A key takeaway is that teaming up with energy partners prevents bank advisors from becoming energy advisors. That is vital as many other FIs have tried this with limited success. Instead, by having an energy partner, bank advisors can point to a certain phone number or simply ask whether the client would like to be contacted, thereby passing the ball without being responsible for advice in the green area.

**Two strategic ways to go with a different outcome – teaming up with advisory vs. commercial partner**

A key takeaway is the difficulty for FIs to determine the pros and cons of choosing an advisory or commercial energy partner. There is no clear-cut answer to which is the wiser choice. It may even be that the most fruitful solution is to team up with both and propose each of the two partners depending on the client's situation. Below are the main points to consider for the FI.

Introducing the household to an energy advisor: They would typically be able to conduct a 360-degree review of the home and consider all relevant energy renovations. However, such visits typically entail costs, and it is not clear who should cover them. If households had to pay, many might be discouraged from engaging in the renovation. After the energy advisor visits, the household is left with the challenge of finding a vendor that can conduct the energy renovation.

Introducing the household directly to a commercial vendor: This implies that the household would engage with someone who can carry out a renovation. However, a commercial vendor would typically not conduct a 360-degree review of the home and is potentially more interested in pushing renovations to the household that the vendor thinks are most profitable for themselves. This increases the risk that not all relevant or the wrong renovations are being considered.

**Necessary to automate the NEEM Core Solution**
In the six tests, a lot of manual work needs to be automated in future, scaled trials. The cumbersome work created bottlenecks delaying the one-pagers, which caused natural frustrations among partners in the NEEM Hub. A natural next step would be to automate the model flow, which would also reduce the number of partners needed to run the model and produce the one-pagers. Essentially, everything in the model can be automated, making the one-pagers instantaneously produced.

**Take-up from banks rests on data maturity and rate of expansion**
Though feedback from banks and clients has been positive it is clear that the main obstacle in driving the NEEM Core Solution forward is limited data coverage. It is planned to be expanded in Denmark, but less so in the remaining Nordic countries.

## NEXT STEPS FOR THE NEEM HUB

The consortium members of the NEEM Hub have spent the past two years developing and testing the above solutions. The results of the NEEM project have confirmed that the NEEM Core Solution is a relevant and effective instrument in engaging FI customers and spurring action in refurbishing the private household sector. Among FIs, the project has succeeded in strengthening the efforts within the green agenda and readiness to pursue actions that promote green solutions and green loans is now widespread.

There are several promising ways to build on the results and efforts of the NEEM project. In the NEEM project, tests were limited to certain geographical areas due to data constraints. By the end of 2023, data coverage will expand by factor 10+, meaning that FIs can target +100,000 households located close to the largest cities of Denmark. A natural next step for the NEEM Hub would be to use the increased data coverage and scale the efforts significantly.

In addition to continuing the work by scaling the efforts, we suggest refining and automating the NEEM Core Solution. In the test so far, the one-pagers have been produced manually. In further tests, this should be automated such that digital energy screenings are quickly and easily produced based on data input.

Another interesting topic to explore is optimising outreach channels. Having automatised value chains allows us to reach out to 200 or 2,000 clients. So far customers have been contacted by phone, which is not cost-efficient when reaching out to 2,000 clients. A fruitful next step could be to test alternative outreach approaches such as different versions of digital letters and webinars.

A final promising road to pursue is to assist FIs and commercial partners in transferring the business model outside the Nordics. Both FIs and the commercial energy partners have stated their explicit interest in this. As the Nordics in some areas are quite far, this road may be the most interesting to pursue in terms of accelerating the green transition.

# REFERENCES

Brohus et al. (2010): Influence of occupants' behaviour on the energy consumption of domestic buildings. Aalborg University, Denmark.

Copenhagen Economics (2015): Do homes with better energy efficiency ratings have higher house prices? Econometric approach.

Copenhagen Economics (2021): Does One Size Fit All? - Impact of Minimum Energy Performance Standards in the revision of the Energy Performance Building Directive. Available at link. Accessed on 09.05.2023.

Energistyrelsen (2018): Status for Energimærkningsordning for Bygninger. Technical report. Available at link. Accessed on 18.04.2023.

Energistyrelsen (2020): Danske nøgletal 2020. Available at link. Accessed on 10.03.2022.

European Environment Agency (2022): $CO_2$ performance of new passenger cars in Europe. Available at link. Accessed on 18.04.2023.

Eurostat: Labour cost levels by NACE Rev. 2 activity [LC_LCI_LEV]. Available at link. Accessed on 18.04.2023.

Eurostat: Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates [PRC_PPP_IND]. Available at link. Accessed on 18.04.2023.

Eurostat: Structure of labour cost by NACE Rev. 2 activity - % of total cost [LC_NSTRUC_R2__custom_4684071]. Available at link. Accessed on 18.04.2023.

Haldi and Robinson (2011): The impact of occupants' behaviour on building energy demand. Journal of Building Performance Simulation, 4(4):323–338.

Rasmussen et al. (2020): Method for Scalable and Automatised Thermal Building Performance Documentation and Screening. Energies 2020, 13(15), 3866.

ROCKWOOL Group (2020): Why renovation makes economic sense. Available at link. Accessed on 11.05.2023.

Statista: Leading banks in the Nordic countries in 2021, by total assets. Available at link. Accessed on 18.04.2023.

Statistics Denmark (2023): BYG42: Byggeomkostningsindeks for boliger. Available at link. Accessed on 18.04.2023.

Statistics Norway: Construction cost index for residential buildings [08651]. Available at link. Accessed on 18.04.2023.

Statistics Norway: Price index for existing dwellings [07230]. Available at link. Accessed on 18.04.2023.

Svensk Mäklarstatistik: Prisutveckling. Available at link. Accessed on 18.04.2023.

Wingfield et al. (2011): Comparison of Measured Versus Predicted Heat Loss for New Build UK Dwellings. Unpublished Data, Leeds Metropolitan University, UK.

Wittchen et al. (2017): Varmebesparelse i eksisterende bygninger. SBI, 16, 2017.

Yoshino et al. (2017): IEA EBC Annex 53: Total energy use in buildings – Analysis and evaluation methods. Energy and Buildings, 152:124–136, 2017.

Yu et al. (2011): A systematic procedure to study the influence of occupant behavior on building energy consumption. Energy and buildings, 43(6):1409–1417, 2011.

APPENDIX A

# TECHNICAL APPENDIX: DATA FOUNDATION AND PROCESSING

This appendix outlines in detail the data-gathering process, data sources and data challenges, in providing the data foundation for the NEEM Core Solution and the tests described in the report. Further, we provide an overview of the primary data preparation principles and steps involved in merging multiple datasets from diverse sources.

First, we outline the sources and the data-gathering process for each of the three data types: energy consumption data, static building data and weather data. We then discuss data quality and challenges in streamlining and cleaning the data, making it ready for use.

Second, we go into detail about data preparation. Here, we focus primarily on the Danish demonstration site, given Denmark's superior data availability and high test participation rate. We briefly present the dataset preparation for the other Nordic countries. Additionally, we describe the challenges and solutions associated with data preparation for all the demonstration countries.

Third, we outline the interaction process between Center Denmark and DTU data scientists concerning data collection and building energy performance modelling. Additionally, we outline the tools and architecture of the Center Denmark data platform, specifically the version that was used for data hosting throughout the NEEM project period.

## A.1 ENERGY CONSUMPTION DATA

The NEEM-solution requires energy consumption data used for heating to estimate current energy efficiency. Heat consumption types may vary from building to building. We developed and tested the NEEM Core Solution with two energy consumption data types common in the Nordics, namely electricity and district heating. Each data source posed unique challenges. We retrieved the data from private utility companies, either directly or from centralised data Hubs.

Most Nordic countries have a centralised IT system that gathers smart electricity meter data points in one place and thus facilitates data sharing via third-party access and user consent. In Norway it is ElHub, and in Denmark it is DataHub. Generally, these national data hub solutions require an electronic ID (eID) to use their API for data access. This was one of the limitations the data preparation team faced since it was based in Denmark and could not use the Norwegian data hub to facilitate data ingestion. Here, an individual agreement with the relevant electricity provider had to be made.

In the NEEM project, we had to establish several ad-hoc agreements with utility companies to obtain the necessary data for our test. As a consortium, we also explored how to establish agreements with national repositories, yet this proved to be more difficult. This was because many countries have legal requirements that restrict access to open-source national databases, necessitating the need for a registered legal entity within their borders to access the data. As a result, we had to navigate the legal requirements of each country to obtain the necessary permissions and establish the necessary agreements with third-party entities to acquire the data we needed. Although this process was time-consuming and complex, it was critical to the success of the NEEM project and enabled us to complete our test successfully.

On the other hand, the district heating data, which is the most common building heating option in Denmark, did not have a centralised data hub. This means that to use district heating data for the NEEM exercise, we had to create agreements with individual district heating companies. We believe that not having a central energy consumption data hub is one of the biggest hurdles to overcome when applying the NEEM Core Solution to other countries.

To accommodate the dynamic nature of a building's energy consumption, it is important to have data with more frequent time steps. However, in the modelling process, the DTU algorithm for NEEM Core Solutions was also adapted to predict the energy performance based on more coarse time-series data, namely daily average consumption data. Another very important aspect of consumption data is the observation period. Specifically, if data covers the heating season of the year or not, and if it is at least a half year long. Of course, the more historical observations (multi-year time-series data) each building with the same owner will have, the better the DTU algorithm's prediction will be.

## DENMARK

In Denmark, we tested the NEEM Core Solution on single-family buildings that have district heating as the main space heating solution. More than 1.8 million households, corresponding to two-thirds of all Danish homes, are already connected to district heating. The greatest challenge for this consumption data type is that approximately 400 district heating companies are spread over the country. Around 50 of the companies are municipal utilities, covering around 50% of the total Danish district heating supply. The other half of the consumed district heating is supplied by around 350 cooperatives and private companies.

**Data availability**

In general, the district heating providers in Denmark do not have a centrally accessible solution for data sharing like the one for electricity data. Electricity individual clients can access their electricity data via a centralised API, Eloverblik, provided by Energinet. Eloverblik is a platform available to private individuals, businesses and third parties. The purpose of the platform is to provide data about electricity consumption and generate an overview across Denmark and electricity suppliers.

Having a district heating data hub would eliminate the additional step of setting up individual data agreements with a large number of utility providers. Unfortunately, it is not yet possible in Denmark. Thus, one can say that the bottleneck of this demonstration site is the availability of the district heating data.

**Data access, processing and challenges**

We tested the NEEM Core Solution in Denmark for the buildings in the Triangle Region, with the most located in the Fredericia municipality. Additionally, the NEEM project geographic coverage area in Denmark is outlined by the supply areas of the TREFOR Varme and Fredericia Fjernvarme utility companies. The two companies are the main district heating providers in the Triangle Region. Figure 7 and Figure 8 in the main text show the supply areas of the two companies.

Initially, we built the NEEM Core Solution on hourly district heating data where Fredericia Fjernvarme data was the main data source in Fredericia municipality. Regarding the coverage of the Danish NEEM test, more than 25,000 households from the coverage area of Fredericia Fjernvarme and TREFOR Varme could be evaluated with the NEEM Core Solution with district heating as a space heating solution.

We could not fully integrate data with hourly resolution from TREFOR Varme during the project. Therefore, some of the households in the Fredericia area could not be matched for the NEEM test. It is also important to note that TREFOR Varme had a lot of their district heating meters with daily time-series resolution as opposed to hourly. Therefore, the NEEM building energy efficiency prediction model had to be adjusted to accommodate time-series data with daily resolution. This is an example of a structural data quality issue: Hourly resolution is much preferred to daily since temperatures vary a lot during the day. However, the DTU energy performance prediction model must be flexible enough to accommodate such differences in time-series resolution.

Providing district heating data for the DTU algorithm came with its own set of challenges. After providing the initial test dataset to DTU from Fredericia Fjernvarme with approximately 5,500 single-family buildings, it was necessary to correct the data ingestion pipeline from TREFOR Varme to expand the demonstration test area. Since it was discovered that large amounts of older district heating meters with daily time resolution were not ingested in the Center Denmark data platform. This created some delays due to a need to organise extra meetings with TREFOR Varme data specialists.

After solving the data ingestion problems, the data format and quality were next. TREFOR Varme and Fredericia Fjernvarme had varying layouts and formats that needed a setup of individual data-cleaning pipelines. For each data source, it was necessary to extract the relevant consumption data into separate files and rename columns to match the input layout of the NEEM Core Solution requirements.

Additional challenges related to data occurred when the building owners changed the utility company and the data from the new company were not available in the data set, or only available for a brief period. This issue could cause the NEEM model not to converge and evoke unreliable energy efficiency predictions due to a lack of data.

## NORWAY

We tested the NEEM Core Solution on single-family buildings that have electricity as the main space heating solution.

**Data availability**

In Norway, an advanced metering infrastructure for hourly meter readings has been established for all households at the end of 2019. The electricity consumption and production data can be accessed through a data hub called ElHub. ElHub is a central IT system that supports and streamlines market processes such as electricity sales, move-in/-out, termination of supply, and the distribution and aggregation of metering values for all consumption and production in Norway. One can say that ElHub data hub is streamlining electricity data processing and market communications and it serves as a link between the smart meters and the customer.

**Data access, processing and challenges**

In the case of Norway, the NEEM Hub wanted to leverage the data capacity of ElHub. Specifically, ElHub is the Norwegian data hub for the energy sector. It is a centralised system that collects, stores, and manages data related to the production, consumption, and distribution of energy in Norway. ElHub was established to improve the efficiency and effectiveness of the energy market in Norway, by enabling market participants to access accurate and timely data in a standardised and secure way. ElHub serves as a central platform for data exchange between energy companies, grid operators, and other stakeholders in the energy sector. It is owned and operated by the Norwegian IT company, Energi Data Service AS, and is regulated by the Norwegian Water Resources and Energy Directorate (NVE).

During the NEEM project, we recognised the importance of obtaining access to ElHub's data, and therefore, scheduled several virtual meetings with them. However, to allow for data access, ElHub requires an organisation to be legally registered in Norway. After exploring the possibility of registering in Norway, we managed to get Nordea Norway to establish the API gateway to ElHub. Nevertheless, even with the gateway in place, we encountered IT barriers and data privacy concerns when attempting to process the data in Denmark. Moreover, to retrieve the meter ID data, we needed to have consent for all the meter IDs from ElHub. The NEEM test volunteers would have had to approve this directly via the ElHub portal, and they would often be unaware of the existence of ElHub altogether. Thus, test volunteers would have had to create a profile, register and log into the ElHub portal to allow us to gain access to their data. Doing this for every single household in a test seemed unrealistic and highly ineffective. After extensive efforts, we therefore abandoned this approach to testing. Moving forward, we believe future endeavours in Norway should focus on streamlining the process. We understand that SINTEF, the research institute, is exploring the creation of a digital environment with a direct link to ElHub to make the process easier.

After it was decided not to pursue the data download option from ElHub using their API and third-party solution, access to the relevant consumption data was negotiated with Elvia, a Norwegian utility company. The data that we received from Elvia included only the buildings that were selected for the Norwegian test.

In general, the electricity consumption data from Elvia was of high quality. It was not necessary to join the metering data with publicly available static building data since the metering files already contained building area values. Concerning data formatting, it was necessary to extract consumption data into separate files and rename columns to match the input layout of the NEEM Core Solution requirements.

On the other hand, since the consumption data did not contain exact addresses or coordinates, the weather data had to be retrieved using the municipality and postal codes. This data process is described in detail in the description of the weather data.

### SWEDEN

During our data collection process in Sweden, we encountered challenges in obtaining real data agreements from utility companies. We reached out to multiple companies, including Vattenfall and E.ON, through various channels such as phone, email, website, and social media, but in the end, we did not succeed in arranging a third-party agreement.

Instead, electricity data from the utility company SEOM in Sweden was used. SEOM stands for Sollentuna Energi & Miljö, a local energy and environmental company located in the municipality of Sollentuna, Sweden. SEOM provides electricity, heating, cooling, and waste management services to both private households and businesses in the area. SEOM is owned by the municipality of Sollentuna and operates to promote sustainable and environmentally friendly energy practices. In recent years, the company has invested in renewable energy sources such as wind and solar power, and in energy-efficient technologies to reduce its environmental impact. SEOM also offers advice and services to help its customers reduce their energy consumption and carbon footprint. SEOM allows its customers to download their energy consumption data from its website. This feature allows customers to keep track of their energy usage and make more informed decisions about their energy consumption transparently and easily. We used this feature to carry out a NEEM Core Solution test with bank employees from the area. Concretely, 12 persons downloaded their energy consumption data from the last year, and the NEEM Consortium received this in a CSV file. The option to download energy consumption data from SEOM's website remains a front-running user-friendly interface which allowed easy access to data and would allow testing and experimentation to improve the overall environmental impact.

In a pre-test, we were able to obtain anonymised district heating data from Stockholm Exergi in the spring. The data covers Stockholm, which has a high concentration of apartments and limited single-family houses.

Overall, the lack of response from utility companies highlights the need for more streamlined and efficient processes for obtaining data agreements in Sweden.

## A.2 STATIC BUILDING DATA

In most cases, data related to the buildings is obtained publicly from centralised state-owned data sources. This data can be generally accessed using open-source API services or is downloadable. Depending on the implementation, it may be necessary to use a digital signature to gain access which may complicate the process. For example, data about all buildings in Denmark are public and can be viewed and downloaded by anyone from Bygnings- og Boligregistret (BBR).

On some other occasions, utility companies can also provide some information about buildings, but it will depend on each company's data storage system. Here, utility companies may use the data from public data registries, so it may be outdated.

We expected that the data quality is very good since the information about properties is regulated and controlled by state-owned organisations. This expectation was met while working with the data from the Nordic building and property registries. However, one should be aware that sometimes the building data may be outdated due to the slow registration process. This is especially important when the building was renovated, and the heating source changed. this would affect the accuracy of DTU's prediction and thus the results of the NEEM Core Solution.

### DENMARK

**Data availability**
Data about all buildings in Denmark are public. This data can be viewed or downloaded from the Danish building registry, Bygnings- og Boligregistret (BBR) directly.

As an alternative data source to get building floor size, number of floors and information about the building's heating system, the EPC report can be used. The EPC report contains all the relevant information about a building that is obtained through a certification process performed by an energy consultant from a certified company. One can search for information on EPC for a particular building and download the EPC report from the Danish Business Authority (Ehrvervsstyrelsen) Boligejer website.

EPC is mandatory and required for the sale and rental of buildings, new buildings and public buildings over 250 $m^2$. An EPC is valid for ten years unless significant changes are made to the building, which will affect the energy performance. Therefore, it is important to check how recently the EPC report has been updated. One must be aware that a large amount of the energy label data in Denmark is missing.

It is important to mention that the energy label value is not directly used as input into DTU's algorithm and is therefore optional for the NEEM Core Solution if the static building data have already been obtained from the public registry.

**Data access, processing and challenges**
The static building data from BBR was available for download using the public API, Danmarks Adressers Web API (DAWA). Here all the relevant information was located in multiple tables. Therefore, it was necessary to download all the tables separately and perform multiple table joins to retrieve the necessary data. Also, the EPC data of all Danish buildings was downloaded using Energistyrelsen's EMO-Data-service API. Even though the energy label data was not necessary for our model predictions, DTU's data scientists used this data to verify their model predictions and test whether their predictions deviated from those of the EPC results.

On many occasions, the building registry data could be outdated. The responsible agency, the Danish Property Assessment Agency, is aware of this problem and is working on improving data quality.

Among other things, it was necessary to join the address string from the BBR tables together with the address strings from the consumption data table. To increase the address string matching ratio, it was necessary to normalise the strings. The process of address normalisation required some extra verification since the internal systems among the utility companies vary and often do not match the standards of BBR. This creates additional space for error, especially when joining across data tables from different data sources.

## NORWAY

**Data availability**
The Norwegian Mapping Authority (Kartverket) manages detailed public geographical information for Norway and also information about property registry data distribution to users and stakeholders. Here, one can search the information about addresses, buildings and properties.

**Data access, processing and challenges**
The limitation to accessing Kartverket building data was that one must have an electronic Norwegian ID solution to log in and complete the search. The same limitation applies to the energy label data. For a scale-up, this information is crucial, especially when considering the heat source data, which is crucial for the

NEEM Core Solution. Another alternative is to retrieve this information from the utility company if available.

It was not necessary to use the Kartverket service, since the electricity consumption data included the necessary building area values; no additional data processing was necessary for this data type. The values from the consumption data could be directly used in DTU's algorithm.

## SWEDEN

**Data availability**
The Swedish National Board of Housing, Building and Planning (Boverket) is a central government authority which works with issues on how to plan society, buildings and housing. The Swedish Cadastral and Land Registration Authority (Lantmäteriet) is the authority that manages all information on properties in Sweden. Lantmäteriet registers contain up-to-date information on all properties in Sweden.

In principle, the building cadastre data are publicly available for access and can be accessed in the following ways:

1. The Lantmäteriet website: The Swedish Mapping, Cadastral and Land Registration Authority's website provides access to the building cadastre data. One can search for the information on their website or download the data directly.
2. The Swedish open data portal: The building cadastre data are also available on the Swedish open data portal, Öppna data. One can access the data and download them from this portal as well.
3. Through a third-party service provider: Several third-party service providers offer access to building cadastre data. These providers may offer additional features, such as data analysis tools, and may require a subscription or payment to access the data.

Nevertheless, to access building data in Sweden, such as floor size, number of rooms, and heating type one typically need to have a Swedish personal identity number (personnummer) or a Swedish organisation number (organisationsnummer). This is because building data are classified as personal information protected under the Swedish Personal Data Act (Personuppgiftslagen).

Individuals can access building data on their properties by using their personal identity numbers. Accessing and using building data without proper authorisation or consent may be a violation of Swedish data protection laws and can result in legal consequences. Thus, this extra layer became a significant barrier in the Swedish test of the NEEM Core Solution because it required individuals to download this information and give the consortium consent to use them.

**Data access, processing and challenges**
Similarly to Norway, to use the aforementioned e-services to extract building information in Sweden, it was necessary to log in with national digital signatures or eID. This option was not further investigated due to the NEEM project boundaries and limited demonstration case.

The electricity consumption data included the necessary building area values, number of floors and heating system type descriptions. Therefore, no additional work was necessary for this data type and the values could be directly used in the DTU's energy performance prediction algorithm. However, DTU's algorithm had to be adjusted to be able to use input electricity data and had to be fine-tuned for different heating system types.

## A.3 WEATHER DATA

To accurately predict a building's energy performance, the NEEM Core Solution utilised weather data points from the closest meteorological stations. The NEEM Core Solution and DTU's prediction algorithm require outdoor air temperature, wind speed and global radiation.

Several weather services are available throughout the Nordic region for both historic weather data and forecast data. Since weather data are not GDPR sensitive, meteorological data are often publicly accessible and easy to access. The data can be found either through a file explorer and a click-and-download solution or it can be accessed through an open API service. We used the national weather solution for the Danish and Swedish NEEM tests. In the Norwegian test, the weather data was based on the Copernicus data service. Copernicus is the European earth observation program that provides ground-based and satellite-based weather measurements and forecasts. Essentially, the Copernicus data service contains every possible weather measurement that could be thought of in a fine-grained resolution. However, retrieving data from Copernicus came with the challenge of the extraction of data from the data formats commonly used in meteorology. This challenge is described in more detail under the Norwegian test.

It is important to note that weather observations from different data sources may cause inconsistencies in the energy performance model predictions due to different parameter observation methodologies, if not considered appropriately. This concern can also be addressed by using the Copernicus data service. Furthermore, the Copernicus API solution would eliminate the need of creating separate data ingestion pipelines for each Nordic country and its national meteorological institutes.

### DENMARK

**Data availability**
In Denmark, weather parameters were retrieved from the Danish Meteorological Institute (DMI) data portal. DMI serves the community with meteorological knowledge and data within the Commonwealth of Denmark, the Faroe Islands

and Greenland with surrounding waters and airspace. DMI tasks cover weather, climate and sea, ranging from issuing weather forecasts and warnings of dangerous weather to producing ice information for Greenland and developing future climate scenarios for use in climate adaptation in Denmark. For the NEEM Core Solution purposes, the weather data was retrieved using the DMI Open Data API.

**Data access, processing and challenges**

After registering as a user in the DMI portal, it was possible to freely access DMI's data. Out of the available services, the meteorological observation (metObs) API that contains raw weather observation data, e.g., wind, temperature, and global radiation data, from DMI-owned stations, was used.

We did not encounter any significant data gaps when working with the weather parameter data from DMI. However, some of the closest DMI weather stations did not have global radiation parameters. We solved the issue by taking the data from the next closest weather station that had data related to global radiation.

Since the buildings in the Danish demo site contained coordinates (their longitude and latitude) that were obtained from static building data, it was possible to calculate the Haversine distance to select the closest DMI weather station.

## NORWAY

**Data availability**

For Norway, we retrieved weather parameters using the Copernicus climate programme and downloaded the data from the Copernicus Climate Change Service (C3S) Climate Data Store (CDS), more precisely from the ERA5 dataset.

**Data access, processing and challenges**

To access weather data from Copernicus CDS, it was necessary to create a user profile and retrieve an API access token to download the data. Another difficulty was that the available file formats in CDS were GRIdded Binary (GRIB) and NETCDF formats. It was necessary to extract all the relevant data parts from these files and convert them into CSV files for the NEEM Core Solution. These file formats were not encountered before by the Center Denmark data scientists and created some additional challenges which in the end were solved successfully.

As the buildings did not have precise coordinates, the selection of the weather parameters was based on the postal code for each building. The postal code of each building was mapped to the municipality code and weather parameters were selected based on the coordinates of the municipal area. We encountered no significant data gaps.

### SWEDEN

**Data availability**
The weather data can be retrieved using Swedish Meteorological and Hydrological Institute (SMHI) services. SMHI is an expert agency under the Ministry of the Environment. SMHI's observation stations collect large quantities of data, including temperature, precipitation, wind, air pressure, lightning, solar radiation and ozone. SMHI offers services to build applications using the SMHI Open Data API or downloading files using Explorer to select weather stations and weather parameters.

**Data access, processing and challenges**
For a more scaled-up solution, a data ingestion setup with SMHI Open Data API should be used. However, for a small demonstration case, it was satisfactory to select the closest weather stations to the demonstration buildings and all relevant weather parameters manually.

As not all weather stations that contain outdoor air temperature and wind speed data had solar irradiation data, it was necessary to select another weather station that contained the global radiation parameter. Afterwards, the data were joined using the multiple weather parameter files into a single table to match the DTU's algorithm input and period of the consumption data.

## A.4 DATA AVAILABILITY AND QUALITY ASSESSMENT SUMMARY

After describing all the necessary data to build the minimum viable product for the NEEM Core Solution by data type and country, it is important to look more closely at the data itself and summarise the findings. Having all the relevant data sources is essential for the NEEM Core Solution. Having data of high quality is even better, as this will allow the DTU algorithm of the NEEM Core Solution to estimate the building energy performance with greater accuracy. Even though the NEEM Core Solution is designed to be able to handle some data gaps, the quality of the model's energy performance estimation may deteriorate with too large missing consumption periods or too short observation periods in the heating season.

In this chapter, we take a closer look at the available data and their quality and further describe the processes to select the data for each demonstration site.

### SUMMARISING: CURRENT DATA AVAILABILITY AND GAPS

The tables below provide a brief overview of the three Nordic countries, and the currently available data sources across all data types, based on the descriptions above. See Table 7, Table 8, Table 9, and Table 10.

Data sources are mostly publicly owned/supported or come directly from energy suppliers. For some of the data, alternative sources are accessible for data comparison and quality assessment. If needed, the alternative data sources can act as a replacement dataset.

The weather data have the highest availability since they can be retrieved both from the national meteorological services in all aforementioned countries and from the open EU climate data hub Copernicus. In Denmark, static building data can be freely accessed as public data. In Norway and Sweden, a national electronic ID (eID) or digital signature solution is required to log in and query specific building data. For the NEEM testing purpose, relevant static building data, i.e., the area and the number of floors for these countries were acquired from the utility companies as an alternative source.

In addition to the utility companies, which are the primary providers of electricity consumption data, Denmark and Norway have public IT systems that can collect electricity production and consumption data and grant third-party secure access to this data.

Table 7
Data availability

| | WEATHER DATA | STATIC BUILDING DATA | | ENERGY CONSUMPTION DATA | |
|---|---|---|---|---|---|
| *Subcategory* | *Temperature, wind speed, wind direction* | *Building information* | *Energy label* | *Electricity* | *Heating* |
| **Denmark** | DMI (dmi.dk)<br><br>Copernicus | BBR | EMO | TREFOR El-net | TREFOR Varme<br><br>Fredericia Fjernvarme |
| **Norway** | Norwegian Meteorological Institute (met.no)<br><br>Copernicus | Kartverket (kartverket.no) | Energimerking (energimerking.no) | ElHub (elHub.no)<br><br>ELVIA | Heating data are not used for this NEEM demonstration site |
| **Sweden** | SMHI (smhi.se)<br><br>Copernicus | Boverket (boverket.se) | Boverket (boverket.se) | Stockholm Exergi (unconfirmed)<br><br>SEOM | Stockholm Exergi (unconfirmed) |

Source: Copenhagen Economics and Center Denmark

## DATA QUALITY AND GAPS

### Quality and gap analysis approach

For the NEEM project, data quality and gaps are assessed using the following approach:

The *Source* column describes the data source. In the case of multiple data providers, the rows are split up and data gaps are described individually for each provider.

The *Quality assessment* column describes the level of data quality. The assessment contains a subjective data evaluation ranging from HIGH, MEDIUM to LOW. This assessment is based on the data availability and observed data gaps.

The *Data gaps* column contains the percentage share of the missing data of the available dataset. For example, <5%, implies that less than 5% of data are missing.

The *Measures taken to counter data gaps* column contains a brief description of contagion plans and actions taken to counter large data gaps.

The buildings' EPC labels are referred to as *energy labels*. Energy label data are optional and mostly used to evaluate the accuracy of the NEEM Core Solution prediction. Additionally, the energy-labelling scale is different across Nordic countries.

**Quality and gap analysis: results by country**

Table 8
Quality and gap analysis table, Denmark

| Data Type | Source | Quality Assessment (High; Medium; Low) | Data Gaps (%) | Measures taken to counter data gaps |
|---|---|---|---|---|
| **Static building data** | | | | |
| Floor size | BBR | High | 0% | No action. |
| Location | BBR | High | 0% | No action. |
| Heat source | BBR | High | 0% | No action. |
| Energy label | EMO | Low | ~50% | Data are optional. No action. |
| **Energy consumption data** | | | | |
| Electricity consumption | TREFOR El-net | High | <5% | Data are optional for this demo site. |
| Heat consumption | TREFOR Varme | Medium | <10% | Improving data ingestion together with the utility company. |
| | Fredericia Fjernvarme | High | <5% | No action. |
| **Weather data** | | | | |
| Outdoor temperature | DMI | High | <1% | No action. |
| Wind speed | DMI | High | <1% | No action. |
| Wind direction | DMI | High | <1% | No action. |
| Global solar irradiation | DMI | High | <1% | Selecting the data from the next closest station if the parameter is missing. |

Source: Copenhagen Economics

Table 9
Quality and gap analysis table, Norway

| Data Type | Source | Quality Assessment (High; Medium; Low) | Data Gaps (%) | Measures taken to counter data gaps |
|---|---|---|---|---|
| **Static building data** | | | | |
| Floor size | Elvia | High | 0% | No action. |
| Location | Elvia | High | 0% | Using postal codes instead of coordinates to retrieve local weather data. |
| Heat source | - | - | - | - |
| Energy label | - | - | - | Data are optional. No action. |
| **Energy consumption data** | | | | |
| Electricity consumption | Elvia | High | <1% | No action. |
| Heat consumption | - | - | - | Data are optional for this demo site. No action. |
| **Weather data** | | | | |
| Outdoor temperature | Copernicus | High | <1% | No action. |
| Wind speed | Copernicus | High | <1% | No action. |
| Wind direction | Copernicus | High | <1% | No action. |
| Global solar irradiation | Copernicus | High | <1% | No action. |

Source: Copenhagen Economics

Table 10
Quality and gap analysis table, Sweden

| Data Type | Source | Quality Assessment (High; Medium; Low) | Data Gaps (%) | Measures taken to counter data gaps |
|---|---|---|---|---|
| **Static building data** | | | | |
| Floor size | Swedbank/SEOM | High | 0% | No action. |
| Location | Swedbank/SEOM | High | 0% | Using postal codes instead of coordinates to retrieve local weather data. |
| Heat source | Swedbank/SEOM | High | 0% | No action. |
| Energy label | - | - | - | Data are optional. No action. |
| **Energy consumption data** | | | | |
| Electricity consumption | Swedbank/SEOM | High | <1% | No action. |
| Heat consumption | - | - | - | Data are optional for this demo site. No action. |

| Weather data | | | | |
|---|---|---|---|---|
| Outdoor temperature | SMHI | High | <1% | No action. |
| Wind speed | SMHI | High | <1% | No action. |
| Wind direction | SMHI | High | <1% | No action. |
| Global solar irradiation | SMHI | High | <1% | Selecting the data from the next closest station if the parameter is missing. |

Source: Copenhagen Economics

**Structural data quality concerns**
Besides the individual dataset data quality, one must be aware of structural issues that can be caused by not using the data appropriately despite the high individual data quality. We identified several significant concerns.

Firstly, one must be aware of the differences in the definition of weather parameters in different climate data providers. To illustrate this, some weather parameters available from the DMI are different from the ones available at Copernicus data services. For example, the wind speed from the DMI is measured at 10 m over terrain and from Copernicus, this parameter is given separately as 10 m u-component and 10 m v-component parameters, which represent the two-dimensional nature of wind direction and wind strength. These differences must be considered in the energy efficiency modelling tool setup, as they can otherwise cause inconsistencies.

Secondly, outdated building data information (Danish building registry database) regarding the space heating system may lead to a faulty energy efficiency prediction. For example, not knowing that additional heating sources like a heat pump in a building have been recently installed, will lead to challenging predictions.

In cases where the building is heated by electricity, it is important to know what the heat source is (direct heating or heat pump) and if building owners have added an EV and are charging it at home. Such cases can alter the model prediction accuracy.

## DATA COLLECTION AND PROCESSING CHALLENGES

**Data collection**
For the NEEM Core Solution to be tested and run smoothly, it was necessary to gather data in one place. The Center Denmark data platform served this purpose. Many data collection challenges were encountered in the process.

The difficulty to access data varied quite a lot depending on the data type. For example, the climate data in all Nordic countries were available as public data and were rather easily accessible and could be integrated via data fetching APIs.

On the other hand, the consumption data appeared to pose the biggest challenge, since all utility companies had individual processes to share data. Among the consumption data types, electricity data have the best availability since many Nordic countries have centralised IT systems (Norway, Denmark) that gather smart meter data points in one place and thus facilitate data sharing. Furthermore, district heating data (in Denmark) provided an extra challenge since a centralised data hub does not exist for this type of data.

**Data processing**
After gathering all the necessary data from the Center Denmark data platform, it had to be transformed into the format that DTU's energy prediction algorithm could consume.

The data processing tasks included dealing with a variety of data formats. First and foremost, time-series data had to comply with the correct date format. Dealing with faulty and missing values added the necessity to pre-process the data extensively. Then joining data from multiple data sources was another challenge, as the primary keys across the different data sources had to be additionally preprocessed. For example, the household address strings in consumption and static building data tables had to be normalised to be eligible for a successful data merge.

Another challenge was locating the closest weather station for buildings that did not have coordinates. This was solved by relying on the zip and/or municipality codes.

It is important to mention another aspect related to data processing namely the use of data processing tools and techniques. The dataset available in Denmark had a significantly higher number of households, and therefore processing data efficiently required using a cluster solution and big data processing tools like Apache Spark. On the other hand, the NEEM tests in Norway and Sweden had less than 50 households and could be solved with more conventional data processing tools I such as the Python pandas library on a single computer.

## A.5 DATA MERGING FOR DTU'S ALGORITHM

In the following, we provide an overview of the primary data preparation principles and steps involved in merging multiple datasets from diverse sources. We focus primarily on the Danish demonstration site, given Denmark's superior data availability and high test participation rate. The dataset preparation for the other Nordic countries is briefly presented. Additionally, we describe the challenges and solutions associated with data preparation for all the demonstration countries.

In terms of data preparation, Center Denmark's main goal was to abide by the agreement made with DTU. After collecting all the necessary data parts, such as consumption, weather, and building data, on the Center Denmark data platform, the next step was to make sure the data was formatted correctly to match the data model and be eligible for DTU's algorithm. To achieve this, the various data from different sources needed to be pre-processed accordingly. Some of the many data processing tasks included:

- Converting date and time values to ensure appropriate time-series format.
- Dealing with faulty and missing values.
- Finding the closest weather station based on building address, coordinates or postal codes.
- Calculating hourly consumption values when the smart metering data was provided as cumulative.
- Normalising address strings from consumption and static building data to properly match the information about the building area and number of floors.
- Joining data among the different data sources and utility companies.

Almost all the aforementioned data processing steps were performed for all demonstration datasets with individual deviations as described below.

The next sections go through the data preparation steps undertaken for each dataset of the Nordic countries. Notably, the demonstration test in Denmark was the most expansive, whereas those in Norway and Sweden were on a smaller scale, necessitating more ad-hoc data processing. Despite the relatively smaller sizes of the corresponding datasets, considerable coordination between the involved parties was required. The individual data processing details are explicated further in subsequent sections.

## DENMARK

In collaboration with Jyske Bank and Nordea, two demonstration tests were carried out in Denmark as part of the NEEM project. The NEEM Core Solution was tested in the buildings of the Triangle Region, primarily located in the Fredericia municipality. The geographic coverage area of the NEEM project in Denmark is defined by the supply areas of TREFOR Varme and Fredericia Fjernvarme utility companies, which are the largest district heating providers in the Triangle Region.

**Center Denmark's data platform - Data Foundation**

As part of the NEEM project, Center Denmark was tasked with collecting data from various sources and consolidating it into a central location. Most of the electricity data and some district heating data from the Triangle Region in Denmark was already available on the Center Denmark data platform and could be used as the basis for the Danish demonstration test. Data from TREFOR Varme and Fredericia Fjernvarme utility companies required additional data-cleaning to match the DTU model requirements.

It is important to mention that the existing Center Denmark data ingestion pipelines covered most of the electricity data but not all the data from the district heating supply areas in the Triangle Region. It was necessary to further expand the district heating data availability on the Center Denmark data platform, as heating data is essential for the DTU energy performance prediction model, and as district heating is the main heating source in Denmark.

Furthermore, we discovered that some parts of the already existing district heating data were not ingested properly and therefore a new data ingestion pipeline had to be created together with the utility company, TREFOR Varme. Additionally, data from these meters had a different data scheme, which required creating a new data processing setup.

**Combining consumption data with building registry data**
To find the relevant building information data, consumption data and Danish building registry data from Bygnings- og Boligregistret (BBR) had to be joined. It was first necessary to place the BBR data on the Center Denmark data platform, for which data scientists had to become familiar with the BBR data model and querying possibilities in the public API, Danmarks Adressers Web API (DAWA). As the relevant information was located in individual tables, it was necessary to download all tables separately and merge them to retrieve all the necessary data, based on the address of each building.

Combining the address string from the BBR tables with the consumption data table required address string normalisation to increase the address string matching ratio. The address strings were normalised (formatted) by converting them to lowercase, removing punctuation, trimming, and removing multiple white-space characters. For instance, "6.Julivej 103, 1. th" was converted to "6julivej 103 1 th". However, given the variations in internal database systems among utility companies and their distinct approaches to controlling data quality, additional verification was necessary.

**Finding the closest weather station**
After joining the consumption data with the BBR data, we added geographical coordinates of the building to the table. From the building coordinates and DMI weather station coordinates, it was possible to calculate the Haversine distance to select the closest DMI weather station. When solar irradiation data was absent from certain weather stations that only provided outdoor air temperature and wind speed data, an alternative weather station with a global radiation parameter was selected.

**Preparing the initial sample dataset**

After agreeing on the data layout, Center Denmark data scientists prepared the first larger sample from the Fredericia Fjernvarme supply area in Fredericia municipality. This dataset contained more than 5,000 buildings. At this stage, it was also necessary to test the NEEM model and its ability to process a much larger number of data points, as well as the processing time.

**Expanding the dataset with district heating meters with daily resolution**
During the first test phase in Denmark, more precisely before testing the NEEM Core Solution with banks and their clients' demonstration sites, the team discovered that in the Triangle Region of Denmark, a large portion of the district heating meters had a time resolution of only one day. At that point, only meters with high resolution (i.e., 15 minutes or 1 hour) were ingested in the Center Denmark data platform. This caused a situation where a new data ingestion pipeline had to be built together with the district heating provider, TREFOR Varme. This added a few days before the test could be smoothly run in Denmark.

After expanding the dataset with the additional district heating meter data (> 20,000 households), it was possible to provide the relevant data foundation for the DTU model. Furthermore, the DTU algorithm had to be adjusted to use the data with daily time resolution.

At the start of the project, the DTU algorithm was developed to estimate hourly energy consumption for a given building. The goal was to create an algorithm to accurately predict yearly energy draw for a given building according to which an EPC label is issued. The hourly temporal resolution was found to be both problematic and unnecessary. It was found that statistically equivalent and computationally simpler results can be achieved using daily observations. This was influenced by various factors described below.

To facilitate large-scale implementation, the DTU algorithm runs by calling C++ model templates through R. This method cuts down computation time from minutes to seconds for a single building. However, the specific implementation is prone to numerical stability issues. These issues are exacerbated by hourly temporal resolution, as the larger required number of observations increases the likelihood of containing erroneous observations that can disrupt the model fitting procedure. In addition, the use of daily instead of hourly values implies a smaller amount of data needed to fit the model, hence further cutting down computational costs.

Another important consideration is data availability. Hourly temporal resolution is only available from buildings with modern meters. It is far more likely for daily energy consumption observations to be available than hourly observations, hence the model can be applied to more buildings and, most importantly, older buildings with likely worse energy performance. Additionally, if hourly observations are available, they can easily be aggregated to daily values.

**Coordinating the data preparation for testing**
After extending the district heating dataset, the testing of the NEEM Core Solution with Danish bank participation could successfully commence. In Denmark, Nordea and Jyske Bank participated in the testing process. Here, after receiving the first bank client addresses, some additional steps were required, mostly to verify the available consumption data. As part of the project, it was investigated, why some of the participants' addresses did not have sufficient data available from the aforementioned utility companies.

**Summary**
Although the Danish demonstration site had the best data availability, it presented unique challenges. Most of the difficulties encountered during the Danish demonstration involved expanding the current data ingestion pipeline. The communication with the relevant utility companies caused some delays in the testing process, but the issue was eventually resolved.

To ensure enough time for error correction, the data preparation team must agree on the desired content, layout, and format of the data early in the project. This requires early and regular collaboration with the model development team and clear communication among all parties regarding the current availability of data.

## NORWAY

The Norwegian test was conducted with 50 employees from Elvia, a utility company in Norway. For this, the NEEM Hub set up a third-party agreement to gain access to some of Elvia employees' energy consumption data. Although the test was not linked to bank customers due to the lack of a NEEM Hub legal entity registered in Norway, it was still able to provide valuable household feedback and model calibration for different situations, such as EPC labelling and weather conditions in Norway. Despite this limitation, the test successfully provided important insights and data that calibrated the model and tuned the value chain process. Overall, the test was a valuable opportunity to test the model and present the NEEM Core Solution to the Norwegian Market.

**Obtaining building consumption data**
The consumption data was received from Elvia, a Norwegian utility company. It included only the buildings that were selected for the Norwegian test. The data was received as a one-time CSV file and setting up a data ingestion pipeline to the Center Denmark data lakes was not needed. The electricity consumption data from Elvia was of high quality.

It was not necessary to join the metering data with publicly available static building data since the metering files already contained building area values. Concerning data formatting, it was necessary to extract consumption data into separate files and rename columns to match the input layout of the DTU prediction model requirements.

**Finding the closest weather station**
On one hand, the consumption data did not contain precise addresses or coordinates, making it necessary to retrieve weather data using the municipality and postal codes. On the other hand, the postal codes of each building were mapped to municipality codes, and weather parameters were selected based on the coordinates within the municipality area. In total, weather data was prepared for 18 municipalities in Norway.

**Retrieving weather data from Copernicus**
Weather data was retrieved using the Copernicus climate programme and data was downloaded from the Copernicus Climate Change Service (CDS), more precisely from the ERA5 dataset.

To access weather data from Copernicus CDS, creating a user profile and retrieving an API access token to download the data was essential. However, the available download file formats in CDS were GRIB (and netCDF). These file formats were not previously encountered by Center Denmark data scientists and presented additional data processing challenges. GRIB is a common file format used to store weather data. To convert a GRIB file to a CSV file, it was necessary to follow these steps:

1. Installing a software tool that can read GRIB files, such as Panoply.
2. Opening the GRIB file in the software tool.
3. Extracting the relevant data. This involved specifying the data parameters and geographic extent.
4. Converting the extracted data into a DataFrame and saving the data in CSV format using the Python library Pandas.
5. Verifying the CSV file to ensure that it contains the data in the desired format.

**Dealing with different weather parameters**
No significant data gaps were encountered when downloading the weather data from the Copernicus climate data portal. However, it is important to mention that the weather parameters that were available in Copernicus were slightly different than the weather parameters extracted from the national meteorological services:

- 2 m temperature (K)
- 10 m u-component of wind (m s-1)
- 10 m v-component of wind (m s-1)
- Surface solar radiation downwards (J m-2)

Since DTU's model was at first developed based on the Danish test data and input weather data was based on the parameters from the DMI, the DTU's algorithm needed to be adjusted for the weather data.

As an example, the wind speed parameter was provided as a 10m *u-* and *v-component of wind*. These are the eastward and northward components of the 10m wind, respectively. These parameters can be combined through simple trigonometry to give the total wind speed. The *2m temperature* parameter has units of kelvin (K), where the temperature had to be converted to degrees Celsius (°C) by subtracting 273.15. The units of *Surface solar radiation downward* parameter are joules per square meter. To convert to watts per square meter, the accumulated values should be divided by the accumulation period expressed in seconds.

## SWEDEN

The Swedish test was conducted with data from 12 houses. The participants were all part of Swedbank's network, primarily employees. All houses were located in Sollentuna, near Stockholm. The utility company SEOM was the energy provider for all houses. Each household would log in to SEOM's website, download their electricity heating data manually, and send it to Swedbank including information on the house area and heating source (heating pump or direct heating).

The approach in Sweden for the test was more manual than the other tests and included more involvement from the participating households, something that is otherwise against the principles of the NEEM Core Solution. We also contacted other utility companies such as EON, Vattenfall and Stockholm Exergi but it was not possible to enter into a proper data agreement with them.

**Obtaining building consumption data**

A single CSV file, containing only the test-related data, was received, obviating the need for establishing a data ingestion pipeline to the Center Denmark data lakes. The electricity consumption data required minimal pre-processing. Given that the table files were formatted in wide format, it was essential to transpose them into a long format to comply with the input criteria of the DTU algorithm. The electricity consumption data was equipped with the necessary static building information and heating system type descriptions, which obviate the need for additional data preparation. The building area values and data on the number of floors could be directly employed in the energy performance prediction algorithm of DTU.

**Finding the closest weather station**

The weather data could be obtained through the services provided by Swedish Meteorological and Hydrological Institute (SMHI). SMHI provides two options for accessing their data: building applications using the SMHI Open Data API, or downloading files via a data explorer, which enables the selection of weather stations and parameters.

To achieve a more scaled-up solution, a data ingestion setup using SMHI Open Data API is recommended. However, for a small demonstration case, it was sufficient to manually select the closest weather stations to the demonstration buildings and identify all relevant weather parameters.

Due to the absence of solar irradiation data in some weather stations that only included outdoor air temperature and wind speed data, an alternative weather station with global radiation parameters was selected. Following this, the multiple weather parameter files were combined into a single table to match the DTU algorithm input and the time period of the consumption data.

## A.6 INTERACTION BETWEEN THE DATA LAKE AND ENERGY EFFICIENCY PREDICTION MODEL

In the following, we go through the interaction process between Center Denmark and DTU data scientists concerning data collection and building energy performance modelling. Additionally, we outline the tools and architecture of the Center Denmark data platform, specifically the version that was used for data hosting throughout the NEEM project period.

### DATA LAKES OVERVIEW

As part of the NEEM project, Center Denmark was entrusted with the task of collecting data from various sources and consolidating it into a centralised repository.

To support Denmark's transition to renewable energy sources and facilitate energy flexibility across different sectors and stakeholders, the Center Denmark data lakes was established as a national-scale energy data foundation. The data lakes are designed using open-source programs that can be implemented both on-premises and in cloud settings, combining various tools that facilitate big data processing, Machine Learning and Artificial Intelligence (AI).

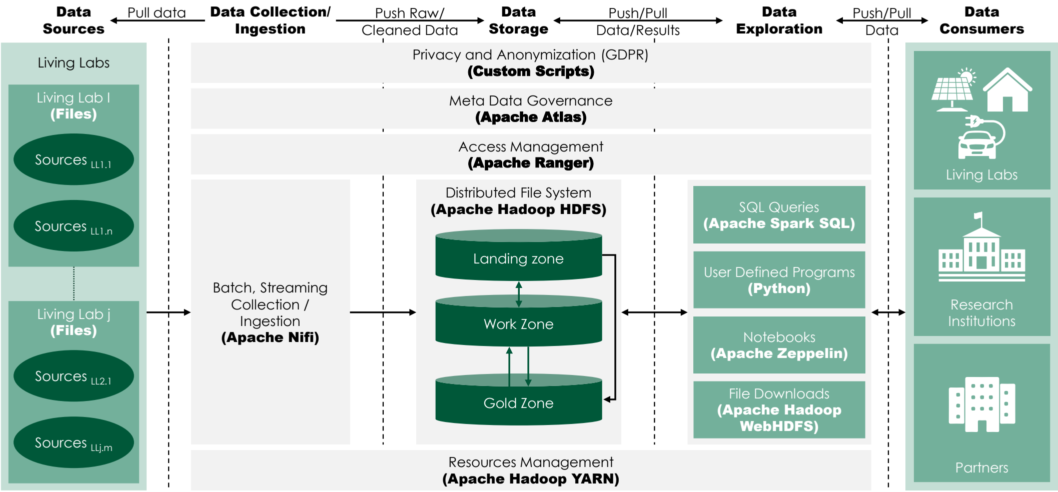
**Accessing data**

Multiple data access and processing options were available on the Center Denmark data platform. Center Denmark data lakes users had different possibilities to run their programs, e.g., using Python, R, Scala, or Bash Shell interpreters, using a web interface offering a Notebook (Apache Zeppelin) environment where users could write their code and interact with the data sources that they were given access to.

**Overall architecture**

Figure 25 below displays schematically the building blocks of the Center Denmark Data Platform. At the top of Figure 25, the data flow represents the various data layers.

Figure 25
Center Denmark data platform overview




Source: Center Denmark

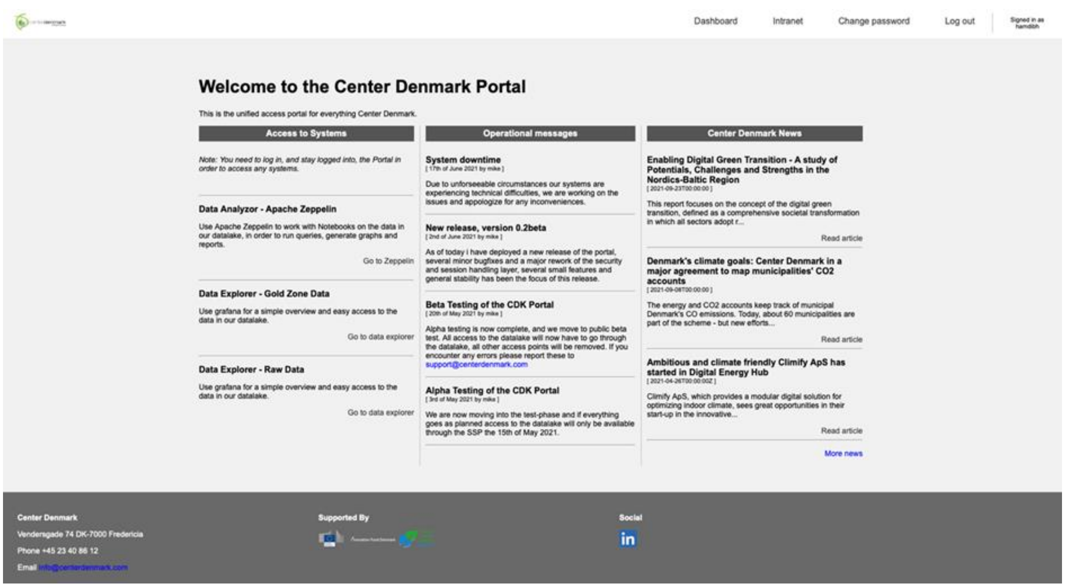
- The **data sources** layer refers to different participants that provide useful information to the energy system. Specifically, Center Denmark collects electricity and district heating data from various utility companies in Denmark, as well as public and open-source data providers that provide information about properties, building energy performance labels and weather data. Data sources also include various Living Labs (LLs)that support testing innovative data solutions.
- The **data collection/ingestion** layer focuses on pulling batches, e.g., energy and customer data, shared by the data sources layer. This layer also ensures loading the data into a dedicated landing repository corresponding to Center Denmark data lakes. The data transfer happens via secure channels since the data contain sensitive information and come from different external systems.
- The **data storage** layer represents the central repository, i.e., Center Denmark data lakes, where the large volume of energy data is loaded.
- The **data exploration** layer allows LLs, researchers, and energy technology companies to explore energy data loaded into Center Denmark data lakes and to run their flexibility tools and solutions directly on Center Denmark data lakes data using different solutions, e.g., SQL queries, running custom programs, or downloading subsets of the data.

- The **data consumers** layer represents the authorised external data users, i.e., LLs, researchers, and energy technology companies, to access data stored in Center Denmark data lakes, or to use data exploration tools.

**Credentials**
At the beginning of the project, the DTU data scientists were provided access to the Center Denmark data platform. The DTU data scientists were given a secure login and password provided by Center Denmark to access the data platform. The credentials gave users the chance to access the different tools offered by Center Denmark data lakes. Additionally, it is important to mention that each platform user only had access to the authorised subset of the data. Thus, only project-related data were made available to the DTU data scientists. Furthermore, building address information was pseudonymised before giving it to the DTU data scientists. The Center Denmark data lakes portal login web page is available following this link: https://portal.centerdenmark.com/.

After filling in the login form, users can select the relevant tool as shown in Figure 26 below to continue working with the data modelling. The available tools were the so-called *Data Explorer* and *Data Analyzer*. For the NEEM project, *Data Analyzer Apache Zeppelin* was the most relevant tool as it supports both data exploration and training the ML models using Python and/or R Programming languages.

Figure 26
Center Denmark portal home page




Source: Center Denmark

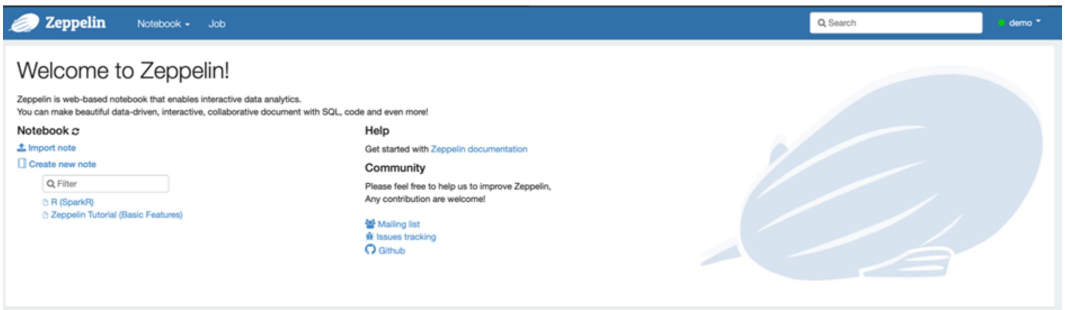
**Connecting to Apache Zeppelin**
Since *Data Analyzer Apache Zeppelin* is the most relevant tool for the development of the NEEM Core Solution, this section gives a short explanation.

At the project execution, Apache Zeppelin version 0.8.0 was available to the Center Denmark platform users.

 is an open-source web-based notebook that enables interactive data analytics like the Jupyter Notebook, which combines data ingestion, data exploration, visualisation, sharing and collaboration features with multiple language backends and support of Hadoop and Spark out of the box. As mentioned, Zeppelin supports running multiple programming language interpreters in the same notebook. This flexibility allowed DTU data scientists to access and explore data and build the NEEM Core Solution using R programming language (preferred development environment by DTU) in the same environment where the data are located. Furthermore, each user can customise their virtual environment to work with the relevant programming language libraries and packages.

It is also advantageous that Zeppelin allows multiple users to work in the same notebook. The Zeppelin notebook URL can be shared among collaborators who have access to the Center Denmark data platform. Apache Zeppelin broadcasts changes in real-time, similar to the collaboration in Google Docs. This flexibility allowed multiple DTU and Center Denmark data scientists to collaborate and work on the NEEM model more dynamically.

Figure 27
The home screen of Center Denmark Apache Zeppelin notebook environment after login




Source: Apache Zeppelin

After the login, the page shows the list of the existing notebooks for the connected user, i.e., R (SparkR) and Zeppelin Tutorial, cf. Figure 27.

**Downloading the data from the Center Denmark data platform**
The Apache Zeppelin web interface supports running user programs directly on the Center Denmark data lakes infrastructure so large amounts of data can be

processed using many machines, avoiding downloading data onto the local machine.

In general, it was recommended to perform the data processing and model development on the Center Denmark data lakes machines as this allowed Center Denmark and DTU to work with very large data sizes and enabled easy sharing of the results.

It was, however, also possible to download the anonymised data from Center Denmark data lakes. To download the data from the Center Denmark data platform users first needed to export the data into their personal HDFS user space, then download the data directly using the Center Denmark data lakes download server (via SFTP) and download the data directly to their local machine. The user needed to run a secure-copy (SCP) command from the terminal.

The first-generation DTU data scientists used this method to access the first test data and develop the NEEM Core Solution in their development environment at DTU.

**About data governance**
Proper data governance was always the highest priority to ensure secure data sharing among the project partners. The access control was enforced so that data sets and files have owners and selected users and groups can be granted access to relevant datasets.

To comply with GDPR, only authorised users could view detailed personal data. Other users could only view data when they had been anonymised or aggregated such that no personal information is revealed. In the project, building addresses and metering IDs were always pseudonymised before giving access to other project partners. This means that Center Denmark data scientists always pre-processed the data before giving them to the DTU data scientists to continue model development. In this way, Center Denmark operated as the intermediary between the various project participants and facilitated the information flow from the data source to the relevant parties that needed access to data.

## COLLABORATION BETWEEN CENTER DENMARK AND DTU

In the NEEM project, Center Denmark's role was to gather all the necessary data from various data sources. Center Denmark data scientists were also responsible for data pre-processing to match the input data layout defined by the DTU data scientists. Center Denmark also operated as the intermediary party to facilitate secure data flow across the project partners.

Data scientists from DTU were responsible for the developing building performance prediction algorithm. At the same time, DTU data scientists investigated how to make the modelling algorithm flexible enough to return accurate EPC labels that comply with the national energy-labelling system in each Nordic country.

**Defining the input data structure**
The input data content and layout for the DTU model were developed in multiple steps and refined along the way. It was important to select all the relevant parameters from each data source together with the DTU data scientists.

The first iteration of sample data contained only a few households. This was the step to align the expectations of the data preparation process concerning the data layout and file structure. Here the DTU and Center Denmark data scientists agreed to prepare a separate file for each data source, i.e., consumption, weather and building data. Additionally, it was agreed to store the consumption data of each house in a separate CSV file. This of course created extra data preprocessing adjustments. Moving from the big data format with thousands of buildings stored in one table layout to being reformatting into a smaller form factor – multiple thousands of files.

**Data and modelling process challenges**
As multiple data scientists from both Center Denmark and DTU were participating in the NEEM project and had to take over work from previous colleagues, some additional inconsistencies and challenges were encountered on the way. This was sometimes caused by limited time for project hand-over and insufficient explanations. The frequent changes within data scientists team caused a necessity to repeat the on-boarding process multiple times thus causing extra workload to both Center Denmark and DTU.

APPENDIX B

# TECHNICAL APPENDIX: ESTIMATING ENERGY EFFICIENCY AND RENOVATION NEED

## B.1 ESTIMATING ENERGY EFFICIENCY

In this section, we describe the model developed to estimate energy efficiency based on the data foundation described in Chapter 1. First, we outline the model on a conceptual level. Then, we describe how the model is used when running the tests in the NEEM Hub. Finally, we present results from the model in the tests.

### THE ENERGY EFFICIENCY PREDICTION MODEL ON A CONCEPTUAL LEVEL

The current EPC labelling procedure combines different measurements of a building (e.g., materials, type of building, heating devices etc.) that need to be collected onsite by an expert in a model that weighs and accounts for all factors. In the end, the model generates an estimate of the primary energy demand.

Because it requires a physical inspection of the house, this method of classifying buildings with an EPC label is time-consuming, expensive, and most importantly uncertain. Moreover, manual classification is not able to assess how the building performs overall and may misclassify significantly.

Several studies have shown that the discrepancy between the actual and estimated energy consumption is significant.[12] One study[13] showed that the difference between the estimated and the actual energy consumption can exceed 100% due to occupants' behaviour.

The IEA EBC Annex 53 report[14] states that the energy consumption of a building is influenced by six main factors: climate; building envelope characteristics (i.e., the surroundings of the house including their material); building services and energy systems characteristics; building operation and maintenance; occupant activities and behaviour; and indoor environmental quality provided. A similar categorisation is found in (Yu et al. 2011).

12 Haldi and Robinson (2011): The impact of occupants' behaviour on building energy demand.
13 Brohus et al. (2010): Influence of occupants' behaviour on the energy consumption of domestic buildings.
14 Yoshino et al. (2017): IEA EBC Annex 53. Total energy use in buildings – Analysis and evaluation methods.

As stated above, a major factor in energy performance is occupant behaviour. However, only a minor focus has been placed on human interaction with buildings when estimating the buildings' thermophysical properties (i.e. heat-related properties). A building's heat consumption and dynamics can be heavily influenced by occupants' changing preferences for the indoor environment, and operational staff's adjustments of the energy systems might lead to significant disturbances when modelling a building's heat consumption. The research done in this project addresses this.

The discrepancy between the anticipated energy consumption and the actual is, however, not only limited to occupants' behaviour. Several studies have shown that discrepancies between the thermal properties of buildings prescribed in the design and reality can vary significantly. A study from 2011 found that 18 out of 18 (100%) newly built British dwellings had a significantly higher HLC than anticipated in the design when it was assessed by co-heating methods, a technique used to measure the heat loss of buildings.[15] The Danish Energy Agency also found that 23% of the EPC labels issued in 2018 were misclassified, and 21% and 31% were misclassified in 2017 and 2016, respectively.[16]

A pertinent example of the physical factors influencing energy consumption in the Scandinavian climate is leaky windows. However, in a manual examination of the building, it may be difficult to identify a single leaky window, and even if it can be identified, it is nearly impossible to determine the leak's contribution to the additional heat consumption. How much does the leak affect the energy performance of the building? How should it affect the EPC label of the building?

Consequently, the discrepancies between the intended building energy performance and the actual performance are hard to quantify as the effects of building characteristics are difficult to separate from the occupant-related effects in practice.

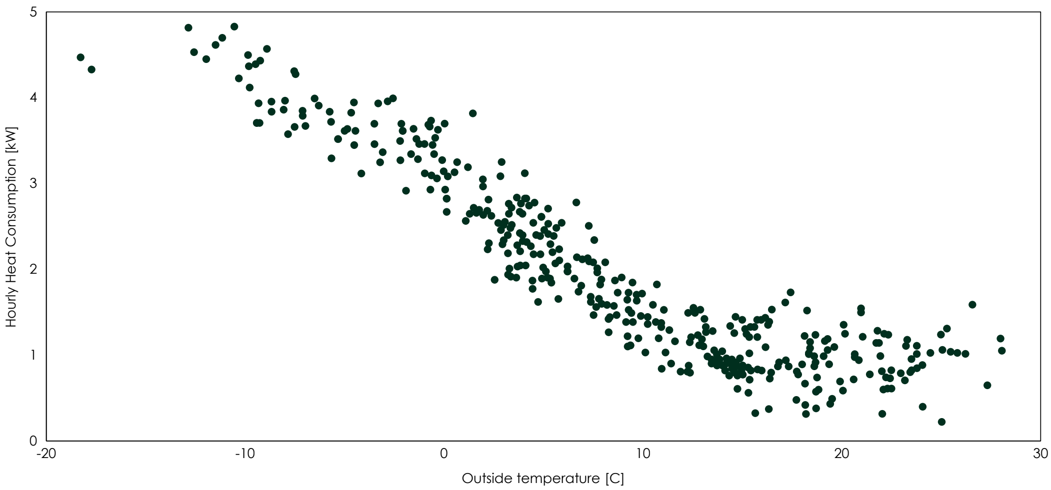
The most intuitive and reliable way to visualise the heat consumption of a building is the energy signature approach. The energy signature describes the relationship between heat consumption and outdoor air temperature.

---

15 Wingfield et al. (2011): Comparison of Measured Versus Predicted Heat Loss for New Build UK Dwellings.

16 Energistyrelsen (2018): Status for Energimærkningsordning for Bygninger.

Figure 28
Heat curve of a typical district-heated house in Denmark
kW




Source: Danish Technological University for NEEM Hub

Figure 28 above illustrates the relationship of a typical Danish building. It shows that the heat consumption and the outside temperature have a negative, linear relationship until about 10 degrees Celsius where it becomes constant.

As such, the energy signature is often approximated as a linear function of temperature. However, it can be more aptly described as a sigmoid function (i.e., a function with an "S" shape that assigns an input value and an output value between 0 and 1) as the heating capacity of the energy system becomes saturated in extreme conditions. However, for simplicity, we assume that the relationship is linear.

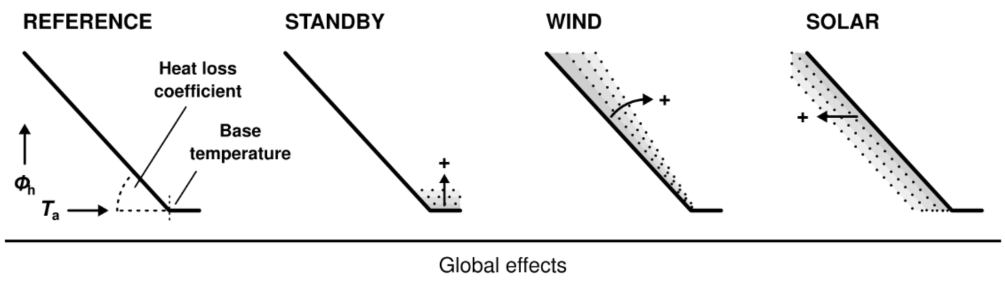
The slope and intercept of even the simple linear approximation carry meaningful information about a building's energy performance. For instance, the slope represents the HLC of the building, which describes the rate of heat flow through the building's envelope when a temperature difference exists between the indoor air and the outdoor air under steady conditions.

During periods where the heat consumption is less responsive to weather changes (e.g., during summer), it is modelled as a constant for buildings without cooling and heat recovery. The turning point from the weather-dependent period (heating period) to the weather-independent period is described by the base temperature ($T_b$). The best temperature of the building is the temperature at which it is in thermal equilibrium with the outside temperature. It can be thought of as the operating temperature of the building. Higher $T_b$ often means higher heat loss at lower ambient temperatures.

While the relationship between heat consumption and ambient temperature can often be described as linear, its relation to other weather phenomena such as wind and solar is more complicated. Nevertheless, energy signatures can be used to visualise their influence and gain information on the building's condition.

Let us now consider the model-theoretical corollary to Figure 28. Figure 29 shows the stylised relation between the ambient temperature of the house and the heat consumption, i.e., the heat curve of the building. This relation is the relation which is shown empirically in Figure 28. Common effects in Figure 29 include increasing standby energy needs of the building, wind's effect on heat loss, and solar radiation heating the building. The HLC (the slope) and the base temperature (transition point) are highlighted.

Figure 29
Heat curve and its responses to common effects

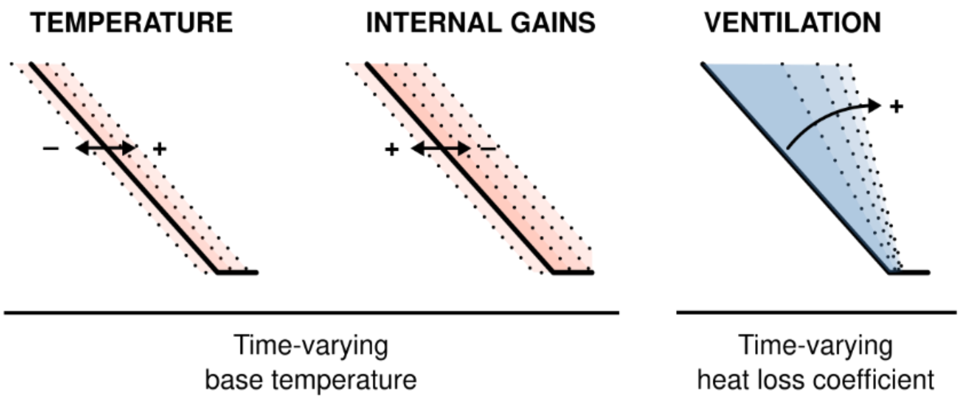



Source: DTU

Figure 29 above illustrates how the HLC of the building is influenced by the wind, and how the entire energy signature is shifted by solar radiation. Solar radiation warms up the building by entering the house through windowed surfaces and direct induction into the building's material thereby decreasing the difference between the inside temperature and the ambient temperature, hence decreasing the need for heating. However, solar radiation does not affect the HLC as the house does not become better or worse at keeping heat. Windy conditions, however, increase the HLC as the building bleeds heat faster when cold air enters, and hot air leaves the house. In both cases, the effects can be modelled as a function of the wind speed and solar irradiation as long as one has data on the two variables.

Similarly, we can model how ventilation and changes in indoor temperature affect the heat curve. Figure 30's two red sub-plots show how the effect of changing indoor temperature and internal heat gains alter the base temperature, and the last blue sub-plot shows how the ventilation rate alters the apparent HLC. Again, changes in internal heat gains and indoor temperature change the heat consumption for a given ambient temperature but do not change the HLC. Ventilation, however, changes the HLC as the house loses more heat when e.g., a window is open.

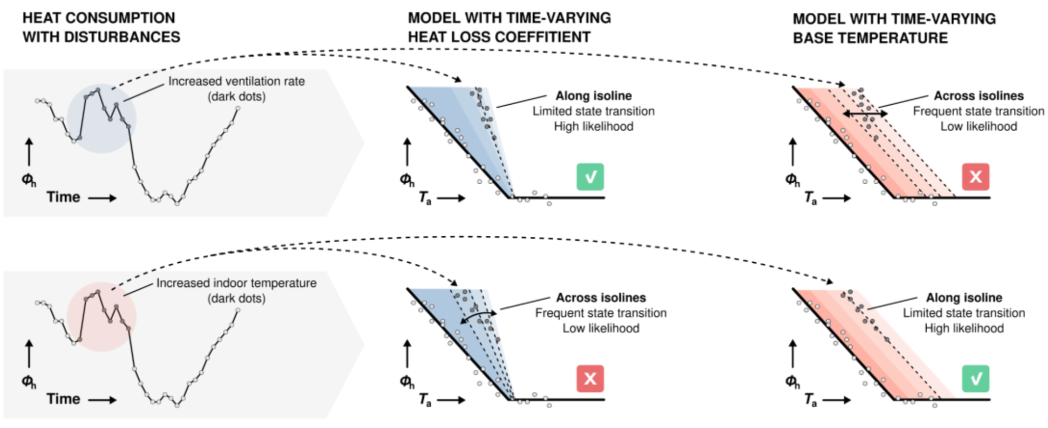
Figure 30
Effect of changing indoor temperature and internal heat gains on base temperature




Source: DTU

For other effects driving heat consumption, such as changing indoor temperatures, internal heat gains, and ventilation rates, measurements of relevant variables are in many cases infeasible to obtain. These are visualised in Figure 31 which shows a conceptual illustration of how two fundamental types of disturbances (changing ventilation rate and indoor temperature) affect the energy signature, and consequently how they dictate which model to use. It demonstrates one of the difficulties in attributing disturbances in heat consumption to appropriate weather effects. The figure displays two apparently identical heat consumption time-series. In both cases, nine of the observations experience an unknown disturbance, marked with a blue and red-shaded circle, respectively.

Figure 31
Disturbances and the effect on the energy signature




Source: DTU

In the first row of Figure 31, the disturbance is caused by an increased ventilation rate and hence an increased heat consumption (dark dots in blue circle). In the second row of the figure, the disturbance is caused by an increased indoor temperature and hence an increased heat consumption (dark dots in red circle). In the first scenario, the data can be modelled by including a time-varying HLC or a time-varying base temperature as shown in the first row, second and third column, respectively. Choosing the model with a time-varying HLC, it is possible to explain the disturbance as a single increment in the ventilation rate (i.e., a one-time change in the HLC). This becomes apparent by the fact that all dots arrange nicely around the dotted isoline. On the other hand, when choosing the model with a time-varying base temperature, the disturbance can only be explained equally well by several subsequent changes in the base temperature. This is shown by the fact that dots cross multiple isolines.

Regardless of which approach is correct, assigning the most accurate model for a variety of buildings autonomously poses a substantial challenge. This project undertook and developed several approaches to tackle this, and it was paramount to find an accurate model describing the most common disturbances experienced by each building.

If the energy signature is well estimated (i.e., the effects of weather phenomena on the energy signature are well captured), then the simulation of a building's total energy expenditure over a year becomes trivial. With models that can accurately estimate the yearly energy expenditure of a building, the assignment of an EPC label becomes an exercise in only knowing the correct legislation for each country.

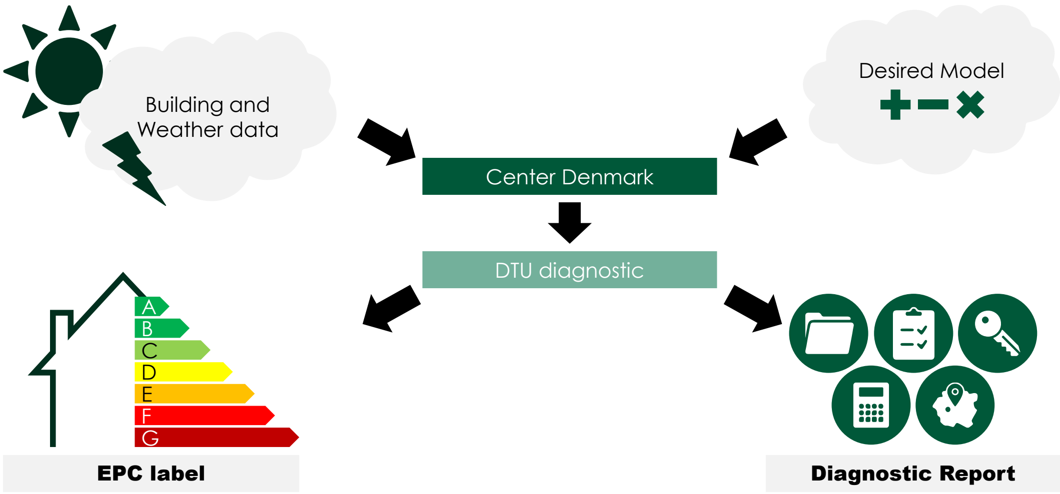
## ESTIMATING ENERGY EFFICIENCY IN THE NEEM HUB

The previous sections outline the energy efficiency prediction model on a conceptual level. This section describes how the model was used for running the tests in the NEEM Hub.

**Model for automated EPC estimation**

The goal was to adapt the previously showcased research into a largely automated energy efficiency modelling framework. This project produced an R-based software environment which leverages the modularity of the energy signature models to forecast the yearly energy consumption of buildings and consequently assign them an EPC label. The NEEM Core Solution's EPC labelling software functionality used in the project, described below in Figure 32, has been developed by DTU and Center Denmark.

Figure 32
Visualisation of NEEM Core Solution's EPC labelling software functionality




Source: NEEM Hub

## B.2 RESULTS FROM THE DTU MODEL

### DENMARK

Danish testing consisted of three distinct studies. Two were carried out with partner banks, namely Nordea and Jyske Bank. The last test was carried out on a large sample of Danish buildings (anonymised data from Center Denmark). As the software was natively created to perform on district heating data, the buildings were evaluated via the extended energy signature models presented in D2.3 from the NEEM hub with the title "The Energy Performance Certificate Predictive Model".

In this study, the first iteration of the data structure was tested, where the weather data and every building's consumption data were kept in separate files to minimise data usage. This approach worked well; however, it was very difficult to maintain due to complexity of data structure when adding many cases.

**Nordea test**

The first Danish test study was carried out together with Nordea Bank where 14 out of 15 supplied buildings were assigned an updated EPC label via DTU software (for the last household, data did not converge, thus not giving robust results).

Table 11
Nordea test results, Denmark

| Building Number | Old EPC | NEEM - EPC estimated |
|---|---|---|
| 1 | NA | C |
| 2 | C | C |
| 3 | E | D |
| 4 | NA | C |
| 5 | NA | C |
| 6 | C | D |
| 7 | C | C |
| 8 | NA | D |
| 9 | A2010 | A2010 |
| 10 | NA | D |
| 11 | A2015 | B |
| 12 | A2010 | A2010 |
| 13 | D | D |
| 14 | NA | B |

Source: DTU

As can be seen from Table 11, the new EPC estimates are generally in alignment with the old, apart from a few notable exceptions.

**Jyske test**
The second Danish test study was carried out together with Jyske Bank where 42 buildings were provided for evaluation. Out of the 42 buildings, 41 were successfully evaluated (for the last household, data did not converge, thus not giving robust results). The buildings were evaluated using all three model types presented in D2.3.

As can be seen from Table 12 below, comparing the conventionally assigned EPC labels to those assigned by the DTU methods shows no alignment. However, the newly estimated EPC labels have neither an optimistic nor a pessimistic trend. The project believes these estimated EPC labels to be a fair assessment of the building's current performance. The model predictions were independently validated by CE.

In addition to the above test studies, approximately 20,000 Danish buildings supplied with district heating were tested. The results of this test are not presented in this report for conciseness.

Table 12
Jyske Bank test results, Denmark

| Building Number | Old EPC | NEEM - EPC estimated |
|---|---|---|
| 1 | NA | E |
| 2 | NA | F |
| 3 | NA | C |
| 4 | D | E |
| 5 | NA | E |
| 6 | D | C |
| 7 | NA | E |
| 8 | C | D |
| 9 | D | C |
| 10 | NA | D |
| 11 | NA | D |
| 12 | NA | E |
| 13 | NA | E |
| 14 | NA | E |
| 15 | C | D |
| 16 | C | C |
| 17 | NA | E |
| 18 | NA | D |
| 19 | C | C |
| 20 | NA | D |
| 21 | NA | D |
| 22 | NA | D |
| 23 | NA | E |
| 24 | F | D |
| 25 | NA | D |
| 26 | D | D |
| 27 | G | C |
| 28 | F | D |
| 29 | NA | C |
| 30 | NA | D |
| 31 | C | C |
| 32 | C | G |
| 33 | C | D |
| 34 | NA | D |
| 35 | E | D |

| | | |
|---|---|---|
| 36 | D | C |
| 37 | C | D |
| 38 | C | C |
| 39 | D | C |
| 40 | C | D |
| 41 | E | D |

Source: DTU

## NORWAY

In the Norwegian test study, 27 buildings were examined, all of which were heated through electricity as the main energy carrier. As electricity data was outside of the initial scope for the project, and thus required more care for building evaluation, the project limited the software to the static energy signature models which were presented in D2.3.

Out of the 27 buildings, 24 were given an EPC estimate (for three households, data did not converge, thus not giving robust results). These are as follows:

Table 13
Norwegian test results

| Building Number | EPC estimated | Yearly Predicted Energy Consumption [kW] |
|---|---|---|
| 1 | C | 29,597 |
| 2 | A | 23,909 |
| 3 | C | 22,094 |
| 4 | A | 17,420 |
| 5 | B | 18,198 |
| 6 | B | 22,465 |
| 7 | D | 23,519 |
| 8 | B | 16,453 |
| 9 | C | 14,066 |
| 10 | D | 32,670 |
| 11 | D | 53,907 |
| 12 | D | 30,559 |
| 13 | D | 30,637 |
| 14 | B | 18,376 |
| 15 | A | 18,933 |
| 16 | F | 36,819 |
| 17 | D | 25,563 |
| 18 | D | 21,946 |
| 19 | A | 26,037 |
| 20 | A | 16,421 |
| 21 | B | 21,374 |
| 22 | C | 21,667 |
| 23 | A | 22,925 |
| 24 | G | 27,967 |

Source: DTU

As can be seen from Table 13, the buildings were rather varied in their energy efficiency, with energy ratings covering the entire range of possible EPC labels (i.e., A to G).

For model fit, one year of data was used to train the models, and the models were validated based on model fit and comparison of predicted yearly energy use observed. The model predictions were independently validated by CE.

## SWEDEN

In the Swedish test, data on 11 buildings were provided. Of the 11 buildings, nine were assigned an EPC label with the DTU software. One building was dismissed due to erroneous data, where the dynamics change drastically across the observation period. The second building was unidentifiable due to an EV biasing the data.

During the Swedish test, the final JSON formatted data was employed. This was exceedingly simple to implement for the DTU software. Creating a JSON file for every single building can seem excessive. However, this eliminates any need for data wrangling from the DTU software side, which facilitates substantially smoother operation. Additionally, with a standardised JSON file format, the software can be hosted remotely and called when needed to evaluate specific buildings.

Table 14
Swedish test results

| Building Number | EPC estimated | HLC [W/m²K] | Yearly Predicted Energy Consumption [kW] |
|---|---|---|---|
| 1 | E | 0.66 | 15,641 |
| 2 | G | 1.05 | 17,390 |
| 3 | G | 1.32 | 18,430 |
| 4 | G | 2.08 | 24,049 |
| 5 | F | 0.73 | 14,875 |
| 6 | E | 0.60 | 18,972 |
| 7 | E | 0.42 | 20,781 |
| 8 | G | 0.98 | 19,785 |
| 9 | E | 0.26 | 13,542 |

Source: DTU

As can be seen from Table 14, the EPC labels in the Swedish test were low. This is because the Swedish EPC label criteria are by far the strictest among the countries considered in this project. Some of the buildings were built 100 years ago. As such, extra care had to be taken when examining the savings potential in renovating these buildings. The model predictions were independently validated by CE.

In addition to EPC labels, other building characteristics were examined. The table above presents one such parameter, namely the HLC, which describes the rate of heat flow through the buildings' envelope when a temperature difference exists between indoor and outdoor air under steady conditions.

According to Swedish Boverket documentation, a typical HLC for a single-family home is 0.4, corresponding to a C rating. Most buildings apart from two exceptions, namely buildings 7 and 9, have a much poorer HLC than the C-level reference. Examining other building characteristics, it was found that one building was abnormally influenced by windy conditions, and another had a large baseline draw, suggesting energy-heavy devices within the household.

Additionally, a visual inspection of model fit was largely useful when applying DTU software to electricity data, which is out of the scope of the project proposal. The intricacies of obtaining the results and troubleshooting are covered in Section B.3.

## RESULTS DISCUSSION

This subsection provides a discussion of the Danish results followed by deeper insights into EPC labels as a tool contextualised by the additional test performed in Norway and Sweden.

When examining the first two Danish test results, it is clear that buildings in the Nordea test have far better performance than those in the Jyske Bank test. This is because the Jyske Bank test carried out a pre-selection identifying older buildings with clients in a position to accept a mortgage for the renovation of the building.

In all three Danish tests, the data-driven EPC estimates largely agree with established EPC labels; often they only differ by a single grade. There are a few possible explanations for this vary. First, the EPC label system is categorical with arbitrary separations based on the energy performance of the buildings. If the energy performance of a building is close to a value separating two EPC levels, it may end up on either side of that division depending on the estimation methodology. Second, it is also likely that from the issue date of the past EPC label, the building has undergone changes (renovation or damage) and its heating characteristics have also changed, resulting in better or worse performance.

The DTU's software performed well on the Danish tests, as the main energy carrier for all buildings is district heating, which is what the method is designed to use. District heating data provide a great basis to validate whether the underlying models are correct, as they directly describe the energy required to heat a building.

Substantially more care and consideration were taken during the Norwegian and Swedish tests, as the buildings considered were heated via electricity. Some methodologies for dealing with unique challenges present in electricity measurements are described in D2.3. Apart from difficulties with processing electricity data, the Norwegian and Swedish tests highlighted the inadequacy of the current calculation scheme of EPC labels as a comparative tool for buildings.
Each country considered in this project has its own EPC labelling system, all of which are dependent on the yearly energy consumption of a given building. As the results of the additional tests in Norway and Sweden show, the current EPC does not provide a complete insight into the building energy performance and requires the examination of additional building characteristic. We attempt to explain this in a few simple case examples, where we outline how the developed data-driven methods can overcome these shortcomings.

**Case 1:** All buildings in the Swedish test appear to have poor energy performance compared to the other two countries. The reason is that energy performance requirements in Sweden are much stricter than in Norway or Denmark, thus skewing the resulting label. If evaluated against the Danish EPC requirements, all buildings gain a letter grade or two. As such, EPC labels facilitate little to no comparability between countries. With data-driven methods, the EPC labelling can be made independent of countries by using the same labelling scales.

**Case 2:** Two identical buildings will have different grades depending on where they are geographically located in Norway. They might have the same contemporary insulation, but the building located in the colder climate zone will have a poorer grade due to a lack of geographical adjustment. This can be particularly important in large countries such as Sweden and Norway. Without appropriate adjustment, the label might be misleading even within the same country. With data-driven methods, the EPC labelling can be made independent of a country's climate conditions by using a reference region in the prediction of energy performance.

**Case 3:** A building can have great insulation, but the inhabitants use it poorly. This can be seen in the case of Building 7 of the Swedish test. The building was estimated to consume energy at level E, but its HLC corresponds to that of a building with a C rating. It was found that the building's ventilation losses were very high, which can usually correspond to excessively open windows and poor use of the building's internal ventilation systems. The data-driven methods allow for insights into the characteristics of the building by interpreting the estimated parameters' physical properties. While the use and building energy performance cannot be fully separated, the potential diagnostic insights can provide a detailed understanding of the use and can be leveraged to perform building energy evaluation.

All the above cases underline the lack of information about the actual building characteristics in the current EPC labels. In both Norwegian and Swedish tests, it was necessary to compare the building characteristic estimates provided by the DTU models in addition to just the EPC labels to make a fair assessment of the building. This is due to previously described difficulties in working with electricity data. In the Danish tests, this presented itself as the necessity of an additional step, providing an independent additional building evaluation.

While accurate building characteristic estimation is an ongoing research problem, some basic characteristics, such as the HLC are rather simple to estimate and provide a good additional source of comparison between buildings. This is reflected in the Swedish EPC rules, where a reference level for HLC is provided. Additionally, Swedish EPC guidelines include geographical adjustments that were not present in the other two countries considered. The NEEM Consortium finds the additional building characteristic-based energy performance guidelines valuable and that they should further be developed in the rest of Scandinavia.

## B.3 ESTIMATING THE NEED FOR ENERGY EFFICIENCY RENOVATIONS

Improving energy efficiency is crucial for reducing greenhouse gas emissions and achieving sustainability goals. However, for households, it is not just about knowing their current energy efficiency measured by the EPC label. They also need to determine whether, from a personal perspective, it is attractive for them to improve energy efficiency, and if so, to what extent. Is it relevant to make small adjustments to the house or to conduct a large-scale renovation?

Studies have shown that the most important factor for households deciding to renovate is the financial aspect. Households care about whether a renovation allows them to save money and whether those savings outweigh the costs of a renovation.

To this end, CE has developed a cost renovation model to connect the scientific research conducted by DTU (explained in Chapter 1), with results and recommendations suitable for communicating to households. This model allows us to estimate the cost of an energy renovation for households – for different levels of energy efficiency and its benefits in terms of savings from reduced energy consumption. By conducting a cost-benefit analysis, we can determine whether energy efficiency renovations are profitable and which renovation (if any) is most suitable for a given house.

Our cost renovation model estimates the capital costs of the energy renovation needed and the cost savings from a reduced energy bill, for each EPC label, and then performs a simple optimisation, identifying *if* a renovation is relevant for the household – and if yes, which one.

From a technical perspective, it recommends renovating until the marginal savings are identical to the marginal cost of capital at which point a household's net savings are maximised. Intuitively, for a given house with a given energy standard, it calculates the difference between the cost savings and the cost of capital from conducting the renovation for each EPC label and then compares for which renovation this difference becomes largest. The cost of capital is calculated as the interest payments on a loan, which cover the total renovation costs. The cost savings represent the reduced energy expenses that result from lower energy consumption.

In the following, we describe the characteristics of the cost renovation model and how we estimate the renovation costs and the potential for energy savings. We then go through country-specific adjustments made to the model for Denmark, Norway and Sweden and test results from the different tests conducted across the Nordics. Please note that we report numbers in national currencies, as the NEEM Hub is a Nordic project, and the NEEM Core Solution was testing in Nordic countries, taking into account price levels, consumer behaviour, functioning of markets, etc., in the specific context.

## ESTIMATION OF RENOVATION COSTS AND SAVINGS

The renovation cost model is designed to estimate the costs and benefits of an incremental improvement of the EPC label and analyse whether a renovation investment would be financially attractive.

It uses data gathered in a CE study from 2015[17] conducted for the Danish Energy Agency (DEA), where we screened more than 136,000 EPC label reports and estimated the effect of energy efficiency on sales prices for single-family houses in Denmark. The EPC label reports studied for this purpose list potential renovations that would, theoretically, improve the energy efficiency of a house. They include all renovations that the energy advisor found viable given the existing conditions of the house. However, not all of those viable renovations are financially attractive from an individual point of view. For the renovation cost model, we focused on those renovations that were recommended as profitable renovations by the advisor.

The average investment costs of a renovation that result in an incremental improvement of the EPC label are depicted in Table 15. They are based on the screened EPC label reports produced by the energy advisors and include all suggested energy efficiency improvements, i.e., not only the profitable ones. Note that the investment costs are indicated in DKK per saved kWh. That is, they reveal how expensive it is to save additional energy given a specific EPC label. They do not, however, reflect the total costs. The data shows that investment costs are increasing, for higher energy efficiency. While it is relatively cheap to improve the energy efficiency of a house from EPC label G to F (DKK 21 per kWh), it is more than twice as expensive to improve the efficiency from EPC label B to A. A large body of studies confirms that this is a robust finding.[18]

Table 15
Investment potential and costs

| | **EPC LABEL** | | | | | | |
|---|---|---|---|---|---|---|---|
| | G | F | E | D | C | B | A |
| Option to renovate | 73% | 74% | 76% | 75% | 62% | 18% | 2% |
| Average investment costs (DKK per kWh) | 21 | 27 | 35 | 41 | 47 | 50 | 51 |
| Adjusted investment costs used in the renovation cost model (DKK per kWh) | 5 | 11 | 20 | 27 | 34 | 37 | 38 |

Note: The table shows investment potential and investment costs for houses in Denmark. The investment costs in Sweden and Norway can differ due to different macroeconomic trends over the last few years.
Source: Copenhagen Economics

17 Copenhagen Economics (2015): Do homes with better energy efficiency ratings have higher house prices? Econometric approach.
18 Copenhagen Economics (2021): Does One Size Fit All?, p. 12.

We need to adjust the average costs obtained from the CE study from 2015 to be used in our renovation costs model, as we only recommend profitable energy-efficient renovations. We expect the obtained average costs to be too high as they reflect all viable renovations and not only those that are deemed profitable. We therefore adjust the estimates concerning cost data from other studies.

We collected additional data from studies conducted by Aalborg University[19] and the Rockwool Foundation[20], which found the costs of energy renovations to be smaller. However, we assess that a risk exists that these costs are too low because the studies assumed that energy renovation projects would be carried out together with other renovations (so-called "add-on" renovations), which in turn, would reduce the fixed costs. As a result, we base the renovation cost model on a midpoint between the CE 2015 estimates and those found in the other studies.

Concretely, we adjust the level of the investment costs for label F downwards but assume that the incremental increases in cost between each EPC label would be identical to those estimated by CE in 2015. We accounted for inflation between 2015 and 2021 and applied a growth factor of 10,5%, based on data on price increases in the Danish building sector from Statistics Denmark.[21] Finally, we quality assured the adjusted values for investment costs with the Danish Energy Agency. We base our estimates of cost of capital on a 2% real interest rate, see closer description below.

**How we estimate the costs of renovation**

The CE renovation cost model takes off where the DTU model of estimating the household energy consumption ends. In essence, we use the estimations from DTU's model on energy efficiency (estimated primary energy demand based on heat consumption, building characteristics and the weather) as inputs to our model and combine them with information about heating costs, obtained from the relevant utility company (see Table 16 for an overview of input variables). Based on that, we can estimate how much additional energy savings are needed to improve energy efficiency and climb the ladder of EPC labels. We perform this exercise for every household and thereby receive an overview of the houses' EPC labels and their theoretical potential to renovate.

19 Wittchen et al. (2017): Varmebesparelse i eksisterende bygninger.
20 ROCKWOOL Group (2020): Why renovation makes economic sense.
21 Statistics Denmark (2023): BYG42: Byggeomkostningsindeks for boliger.

Table 16
Input variables to renovation cost model

| INPUT VARIABLE | SOURCE |
|---|---|
| Primary energy demand | DTU model based on input from utility companies |
| Heating costs | Utility company |
| Year of construction | Register data |
| Size ($m^2$) | Register data |

Source: Copenhagen Economics

Generally, this analysis reveals that many houses have a potential for improvement. We observe that more than 95% of the houses included in our Danish version of the model have an energy label of C or lower, which suggests that energy renovations can lead to reductions in energy consumption and savings in yearly energy expenses.

However, our model also reveals that such renovations are not technically feasible (e.g., because the condition of the house does not permit renovation) or financially attractive for all houses. Because a renovation constitutes an investment, it comes with substantial costs and those costs can differ depending on the energy standard that is in place and the standard that is to be achieved.

In the next step, we therefore compile multiple renovation scenarios for every house, where each scenario comprises an incremental improvement to the next best energy label. For example, if a house is currently estimated to have the EPC label F, then our model compiles five alternatives: for an improvement from F to E, from F to D, from F to C, from F to B and from F to A. This analysis is conducted based on the theoretical reduction in energy consumption that is required to improve the energy label. We account for the current consumption and the heating costs given the size of the house and calculate the relative energy reduction needed to reach a new energy label.

To illustrate this step of the analysis, consider a concrete example of a house from our sample (see Table 17): a house with an EPC label F and a size of 180 m$^2$. We estimate that the house has an annual energy consumption of approximately 42,625 kWh. At costs of DKK 0,67/kWh (actual costs obtained from the household's utility company TREFOR; Table ), this amounts to an annual energy bill of DKK 28,452.[22] Given the relevant input variables and the characteristics of the house, we can determine the necessary energy savings required to move to the next best EPC label, that is, label E. To achieve that label, an energy reduction of approximately 16% is required. This would reduce the annual energy bill to DKK 23,897 (i.e., savings of DKK 4,555 per year). The same exercise is conducted for additional improvements. With any incremental improvement of the energy label, the household increases its savings. However, we also find that the marginal cost savings on the energy bill for an incremental label improvement are not linear – in the example from Table 17 they first increase, and then decrease as higher energy efficiency is achieved.

To calculate the total costs of conducting a given energy renovation, we determine the potential energy savings (in kWh) in each scenario, i.e., from EPC label to EPC label. We multiply the energy savings in kWh, with the determined investment costs needed to save one kWh of energy consumption, see in row 5 Table . As expected, we observe that both the energy savings and the estimated costs increase with the EPC label, implying that an improvement of the efficiency is costly but also results in less energy consumption. The recommended energy renovation is where the net savings are largest. For the example below, that would be renovating from EPC label F to C, entailing yearly net savings of DKK 6,189.

22 Note that energy costs can vary substantially both within and between countries. Therefore, it is necessary to apply the correct local costs to determine the potential for energy savings. Moreover, our data for electricity costs reflect the prices from 2022. However, those prices were substantially lower than energy prices in 2023 as a result of the trade embargo with Russia. As such, our estimates for energy savings potential can be regarded as conservative as the savings potential would further increase with higher energy prices.

Table 17
Example: Effects of upgrading EPC label for a given household with EPC label F

| | | F – E | F – D | F – C | F –B | F – A |
|---|---|---|---|---|---|---|
| 1 | Potential energy savings (kWh) | 6,825 | 15,025 | 23,225 | 29,400 | 33,550 |
| 2 | Marginal energy savings (kWh) | 6,825 | 8,200 | 8,200 | 6,175 | 4,150 |
| 3 | Annual cost savings (DKK) | 4,555 | 10,029 | 15,503 | 19,625 | 22,395 |
| 4 | Marginal annual cost savings (DKK) | 4,555 | 5,474 | 5,474 | 4,122 | 2,770 |
| 5 | Total estimated cost of renovation (DKK) | 78,285 | 244,808 | 465,683 | 672,940 | 825,984 |
| 6 | Annual capital costs (2% of total costs) (DKK) | 1,566 | 4,896 | 9,314 | 13,459 | 16,520 |
| 7 | Marginal annual cost (DKK) | 1,566 | 3,330 | 4,417 | 4,145 | 3,061 |
| 8 | **Net savings (DKK)** | 2,990 | 5,133 | **6,189** | 6,166. | 5,875 |
| 9 | Change in sales price (DKK) | 128,716 | 242,860 | 354,576 | 456,577. | 573,150 |
| 10 | $CO_2$ emission savings (ton/year) | 0,49 | 1,08 | 1,67 | 2,12 | 2,42 |

Note: The renovation scenarios illustrate the effects of a potential energy renovation for an example house from our Danish sample with a current energy label F.
Source: Copenhagen Economics

Table 18
Energy Costs for utility companies relevant for tests of the NEEM Core Solution

| UTILITY COMPANY | COUNTRY | ENERGY COSTS |
|---|---|---|
| TREFOR | Denmark | DKK 0.67/kWh |
| Fredericia Fjernvarme | Denmark | DKK 0.4/kWh |
| Oslofjord Varme | Norway | NOK 2.3/kWh |
| EON | Sweden | SEK 0.8/kWh |
| SEOM | Sweden | SEK 0.88/kWh |

Source: Copenhagen Economics

In the decision to make an energy renovation, we need to compare the one-off investment costs with the running savings of a lower energy bill. We therefore convert the one-off investment costs to the running annual capital costs. Capital costs represent the expenses associated with a renovation and thus the minimum return a household expects to receive on the investment. Intuitively, the costs of capital can be thought of as an annual interest payment to a bank which granted the loan to cover the renovation expenses.

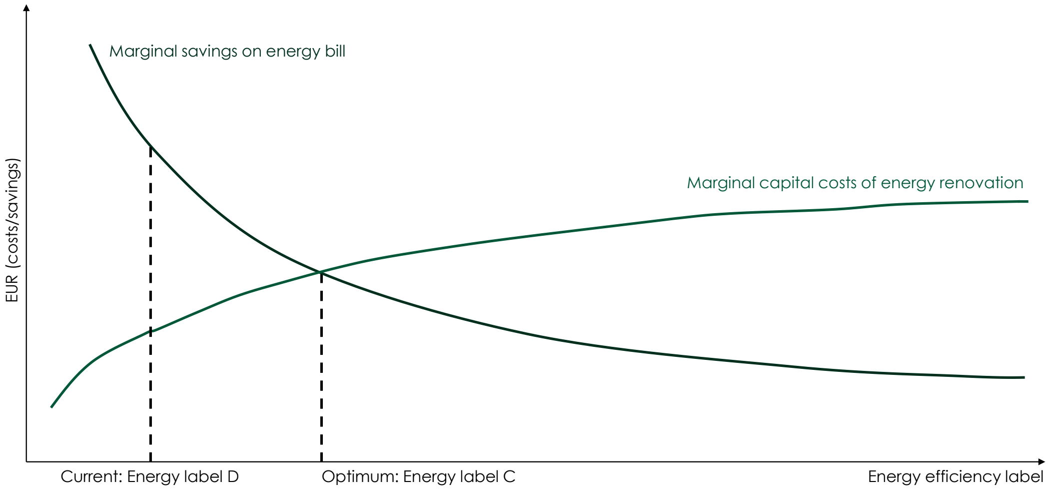
In practice, this is likely also the comparison a household would do; the total renovation costs are often too high to be covered "out of pocket", taking a loan and paying interest is therefore a realistic scenario for many households. Concretely, we assume a real interest rate of 2%, see row 6 Table 17. However, even for households that do not (need to) take a loan, covering the renovation expenses is not for free as they could invest their money elsewhere. That is, the costs of capital can also be seen as the opportunity costs of an investment.

Calculating the annual capital cost and annual savings on the energy bill, we can then compute the difference between the two variables. This allows us to determine net financial benefits, i.e., whether a renovation is financially attractive: if the savings outweigh the costs, the renovation generates a gain; if the savings fall short of the costs, the renovation creates a financial loss. We expect profit-maximising households to conduct a similar cost-benefit analysis and eventually choose the renovation that is expected to generate the largest gain (provided at least one scenario exists that generates a gain).

Our cost renovation model follows this intuition by solving an optimisation problem. It seeks to maximise a household's net savings and does so by finding the intersection of the marginal (capital) cost and marginal benefit (i.e., cost savings) function. As long as the marginal costs are lower than the marginal savings, it is beneficial for the household to invest in additional renovation because it can increase its net savings. Once the marginal costs outweigh the marginal savings, the profit-maximising point has passed, as illustrated in Figure 33.

The example house generates the largest net savings when improving its energy efficiency from label F to label C. Although, relative to its current standard F, all renovations would generate positive net savings, improving the energy efficiency beyond label C would not maximise the financial gain because the marginal cost of capital would exceed the marginal cost savings. Note that the differences in net savings between the discrete changes in EPC labels are rather small. In particular, the marginal change in net savings from EPC label C to label B (DKK 23) is so small that our estimation becomes sensitive to changes in the estimation's input factors. For example, if the energy prices charged by the utility company increased by only DKK 0.01, this would change the outcome of our estimation such that a renovation from label F to B (instead of F to C) would become financially most attractive. It is therefore important to be aware of the sensitivity/uncertainty of our model and treat our estimates with caution.

Figure 33
Illustration: Profit-maximising energy efficiency renovation
EUR




Note: The depicted curves show stylised textbook examples. They do not necessarily correspond with the dynamics of the marginal costs and marginal savings for all houses.
Source: Copenhagen Economics

**$CO_2$ emission savings from energy renovation**
It is important to note that we assume households are primarily concerned with their private costs and benefits and therefore seek to maximise their own profits when conducting an energy renovation. This implies that the recommendation made by our model does not necessarily include the societal benefits of $CO_2$ emission savings. This would only be the case if $CO_2$ emissions were priced incorrectly in the cost of energy consumption (for example through a $CO_2$ tax). Then, the societal benefits would be properly accounted for in the household's decision and the household's financial incentives would be aligned with the societal incentives, ensuring that the trade-off between costs and benefits would guarantee a socially optimal outcome.

Nonetheless, our model calculates the $CO_2$ savings, and we communicate the information to the households. That is, even if the $CO_2$ price is not priced incorrectly, this information can create awareness of the additional societal benefits of an energy renovation. In the following, we describe how our model determines the $CO_2$ savings.

To obtain a benchmark for $CO_2$ savings that follow from the consumption of district heating, our model starts by drawing on 2020 data from the Danish Energy Agency[23] This data suggests that the $CO_2$ emissions per gigajoule (GJ) correspond to 20 kg. Since our estimations for energy consumption are in kWh, however, we need to convert this input measure. We find that 1 GJ corresponds to 277,78 kWh and can therefore deduct that the $CO_2$ emissions from consumption of district heating are 72 grams per kWh (or 0.000072 ton per kWh). Finally, we multiply this value by the energy savings estimated for each renovation scenario. That allows us to determine the $CO_2$ savings as shown in row 10 of Table **.**

In the future, as energy sources become greener, the $CO_2$ intensity of supplied energy will fall. This implies that the $CO_2$ savings from given energy renovations will fall in the coming years.

Although $CO_2$ emissions for energy consumption are usually measured in tons per kWh, this information may not be readily understandable for many households. We therefore decided to also illustrate the information in a unit that is more familiar to people: the $CO_2$ emissions from driving a car, measured in tons per km. We obtained data from the European Environment Agency implying that in 2019 a conventional, fuel-driven car consumed on average 122.3 grams of $CO_2$ per km.[24] Using this value, we can convert the estimated $CO_2$ savings in each renovation scenario and thereby provide a more tangible estimate of the $CO_2$ savings.

**Housing price increases after energy renovation**

One important aspect for house owners is to understand how an energy renovation translates into an increase in the housing price. It matters because it allows a household to sell the gross benefits of the renovation (i.e., the reduced energy expenses) and can affect its decision whether or not to sell the house. In other words, the increase in the housing price represents an *alternative* benefit of the renovation, which the household can choose to reap instead of future savings. For that reason, we estimate to what extent an incremental improvement of the energy renovation affects the house price and communicate the information through our two-pagers to the households.

The estimation of an increase in sales price due to improved energy efficiency is based on Copenhagen Economics (2015). To estimate the causal effect of energy renovations on house prices, we analysed register data on all Danish private single-family houses sold between 2006 and 2014.[25] Of the original 364,000 sales during that period, around 136,000 included an assessment report for the house's energy efficiency performed by an energy advisor. We focus on those so-called EPC label reports and estimate how the performed renovations and the detected potential for further renovations affect the sales price of the house.

23 Energistyrelsen (2020): Danske nøgletal 2020.
24 European Environment Agency (2022): $CO_2$ performance of new passenger cars in Europe.
25 Copenhagen Economics (2015): Do homes with better energy efficiency ratings have higher house prices? Econometric approach.

Identifying the pure effect of energy efficiency, however, is not an easy task. This is because potential confounding factors exist that could bias the estimation and lead to either an overestimation or an underestimation of the true effect. For example, old houses are typically insulated worse than newer houses but may have other characterises that also affect the market price in a systematic way (both positively and negatively). In statistics, such an issue is referred to as *Omitted Variable Bias* and should be accounted for by including the variable as an independent control. For our example, this implies controlling for the year of construction to keep its other potential effects constant and isolate them from the effect of interest – the energy efficiency. In our analysis, we add several control variables, which help us to eliminate the effects of the confounding factors.[26]

To estimate the effect on the sales price in a robust way, we employ three different estimations techniques – a random effects (RE) model, a fixed effects (FE) model, and a matching model. Strengths and weaknesses are associated with all three methods. Each of them approaches the overall question from slightly different perspectives using different assumptions. However, the models complement each other well and if one method gives a different answer than the others, it may be a sign of problems with the assumptions related to the respective model. In the following, we will briefly introduce each model.

With the RE model, we make use of both the time-series information in the data by comparing different sales prices of the same house (if the house is sold multiple times) and the cross-sectional information by comparing sales prices of different houses. To set up our panel data, we include a variable that counts the sales of each house. For every sale, we control for the average selling price in the given municipality in the given quarter and several control variables related to the house, the area and the seller (to be explained below). We assume that this controls for the date of the sale and the timing between sales, implying that there no longer exist any correlations between the sales of different houses. Finally, as a critical assumption, we assume that all other factors that affect the sales prices which are not included in the model (unobserved factors) are unrelated to energy efficiency.

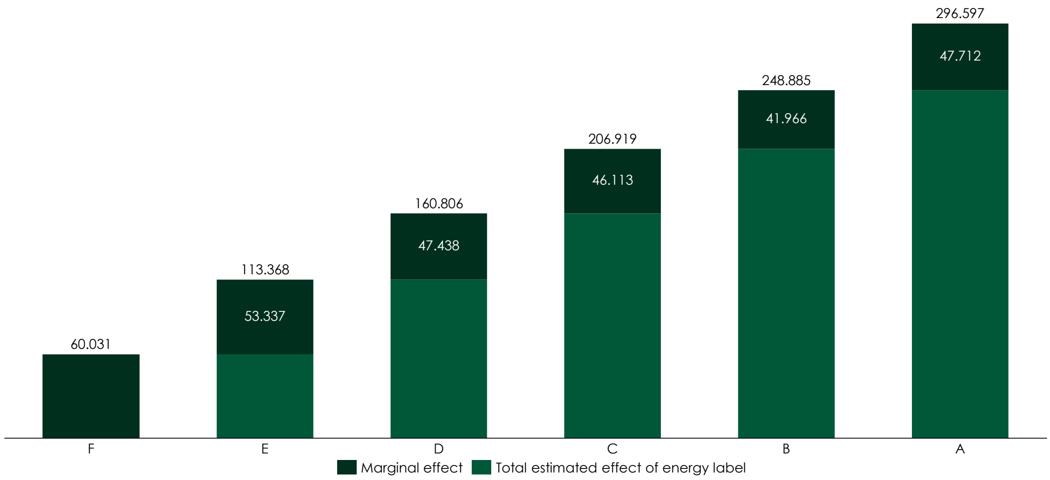
The FE model allows us to capture time-invariant (i.e., time constant) factors. This is useful for the analysis if houses are sold multiple times. For those houses, we would expect that certain characteristics (e.g., the year of construction or the distance to the sea) are constant over time. As a consequence, we can heavily reduce the number of control variables (we only need to control for time-varying factors) because all time-invariant variables drop out from the estimation model by default. This reduces the risk of omitted variables bias.

26 For an overview of the added control variables, see Copenhagen Economics (2015): Do homes with better energy efficiency ratings have higher house prices? Econometric approach.

In our matching model, we conducted a propensity score matching. That is, we matched each sold house with a given energy standard with another house that was (nearly) identical in every aspect but the energy standard. This way, the difference in the sales price can only be explained by the difference in energy efficiency. The approach is akin to a classic experimental approach with a treatment and control condition. However, since the treatment assignment under the matching model is not random, the causal inference gained by the approach crucially relies on the assumption that the matched houses are very similar (ideally: identical). This is a strong assumption, so the results of the model must be considered with caution and mainly serve the purpose of adding robustness.

The RE model provides the most explanatory power in its estimates. The results of the RE estimation are displayed in Figure 34. They reveal the effect of an incrementally improved energy efficiency for a 100 m$^2$ house relative to a house with an energy label G. For example, they suggest that a house with an energy level C sells on average for DKK 207,000 more than a house with an energy label G. Moreover, as expected, every improvement in energy efficiency increases the sales price of the house. The effect is statistically significant for all EPC labels except for the increase from label B to A. The reason is that only a few houses can be improved from label B to A, and so the statistical power to precisely estimate this effect is low.

Figure 34
RE model estimates of house price increase related to improved energy efficiency
DKK




Note: The results relate to a house of 100 sq. m. All effects are measured relative to a G-labelled house. All effects are measured relative to a G-labelled house. The numbers in parentheses are standards errors. ** indicates that the estimate is significant on a 1 % significance level. The model uses 99.686 observations (sales) from 92.232 houses.

Source: Copenhagen Economics (2015)

Our estimations provide the important insight that energy renovations have a substantial effect on the value of houses. Although this value increase of the asset might not materialise immediately (unless its owner plans to sell the house), it is useful information for both the house owner and the financial institution that provided the mortgage. We therefore consider this model estimation an important part of our analysis and highlight the positive effect on the house price in the information brochure through which we reach out to the households.

## APPROACH AND RESULTS FOR DENMARK

The findings in Copenhagen Economics (2015) are based on Danish register data and EPC label reports, and thus behaviours, prices, and scientific research which is specific to the Danish population. The renovation cost model is therefore also country specific. Further, energy usage, energy sources, energy prices and EPC label thresholds are country specific. This should be kept in mind for the development and testing of the NEEM Core Solution.

We make a number of updates and corrections to the results from the 2015 CE study, to be able to use them for market testing in 2022 across the Nordic countries, considering the macroeconomic development from 2015-2022. Concretely, we:

- Use the so-called "building cost index", from Statistics Denmark to adjust for renovation cost prices in Denmark.
- Adjust sales prices according to realised sales prices from Finance Denmark for single-family houses (an average for the entire country).
- Use the average energy costs for the last year provided by the district heating company TREFOR.
- Based on conversations with Fredericia Fjernvarme, which are expecting significant increases in prices from the beginning of 2023, we increase the average district heating price for 2022 by 20% (indicated as the minimum potential increase in prices).

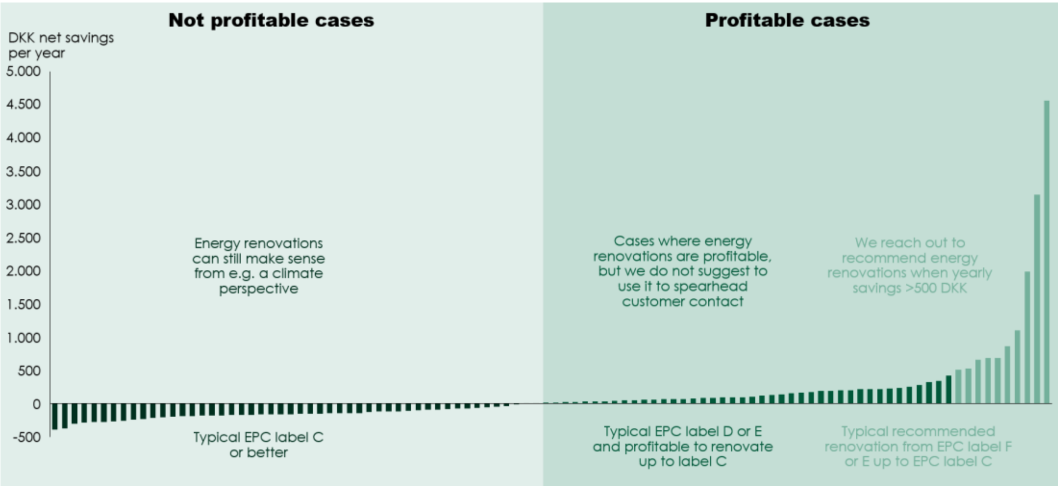
In the following, we go through the tests of the renovation cost model in Denmark. This includes tests on training data, calibration of the model, and two tests with Nordea Bank and Jyske Bank respectively. Section 2.1 described the development of the baseline model. We keep developing and adjusting the baseline model, based on learnings throughout the different tests. We also perform quality assurance and sanity checking of each house analysed, keeping in mind that the renovation cost model is a newly developed model building on theoretical findings, but not real-life evidence on which renovations are possible to carry out.

**Calibration of model**

Before conducting any market testing based on the renovation cost model, we tested it, and calibrated the model accordingly, on a sample of 103 anonymised households from the Triangle Region in Jutland (provided by Center Denmark).

We found it to be profitable to conduct an energy renovation for around half of all analysed houses. However, for many houses, a renovation would only yield a very small financial benefit. Therefore, we assess banks should only reach out to households, where we have larger certainty about the potential for profitable energy renovations – in this case when yearly net savings exceed DKK 500, amounting to around 10% of analysed households cf. Figure 35. For most households, DKK 500 yearly may not be enough savings to warrant the hassle of energy renovations. Yet, because there is uncertainty in our model, it may still be worth examining potential renovations closer even though our model only predicts DKK 500 DKK worth of yearly savings.

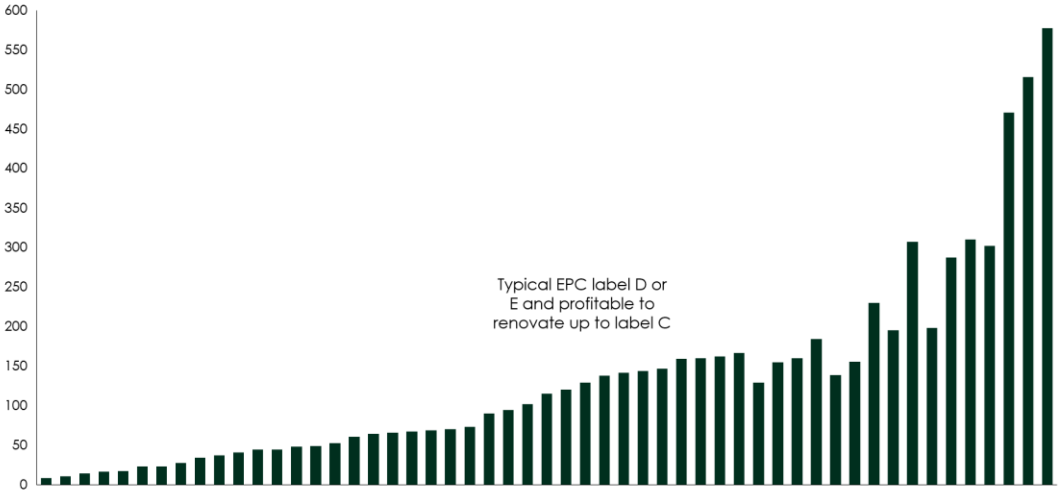
Figure 35
Yearly net savings for optimal level of energy efficiency
DKK net savings per year




Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", and anonymised data on energy consumption and building characteristics for 103 households settled in Fredericia, Denmark.

We find the typical initial EPC label for a profitable case, where *we would not reach out* to EPC labels D or E. Typical initial EPC labels for a profitable case where *we would reach out* are F or G. For most households where an energy renovation is profitable, we find that the optimal renovation level is the EPC label C. In other words, our model suggests that the most profitable renovations are those where houses have very low initial EPC labels. Since those houses also have the highest potential for improvement, their renovations, naturally, happen to have larger capital costs than the renovations for houses with better labels (cf. Figure 36). Nevertheless, they reveal the largest profit margin because their marginal costs are considerably lower than the marginal cost savings on the energy bill. As the labels improve the difference between marginal costs and marginal cost savings shrinks, which implies lower scope for profits. For houses where we recommend reaching out, we typically find a need for investment between DKK 150,000 and DKK 550,000 (corresponding to approximately € 20,000-74,000).

Figure 36
Renovation cost for houses where renovation was profitable
Thousand DKK




Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", and anonymised data on energy consumption and building characteristics for 103 households settled in Fredericia, Denmark.

We assure the quality of our model and its results with energy efficiency experts, and officials responsible for the EPC label system in Denmark from the Danish Energy Agency. The size of the investments needed to improve energy efficiency and the energy efficiency/EPC label we find to be optimal are in line with the Danish Energy Agency's expectations. However, there are no clear guidelines for the expected costs of energy efficiency renovations, and the research in the area provides very different estimates, as described in Section 2.1.

Overall, we find that our model results are sensitive to the model's input factors such as energy prices. Further, net savings will in most cases be relatively small – as costs for renovation would almost offset the savings on the energy bill – for the optimal EPC label. We incorporate conservative assumptions in the cost renovation model, making sure only to reach out with recommendations to conduct energy renovations when results are robust.

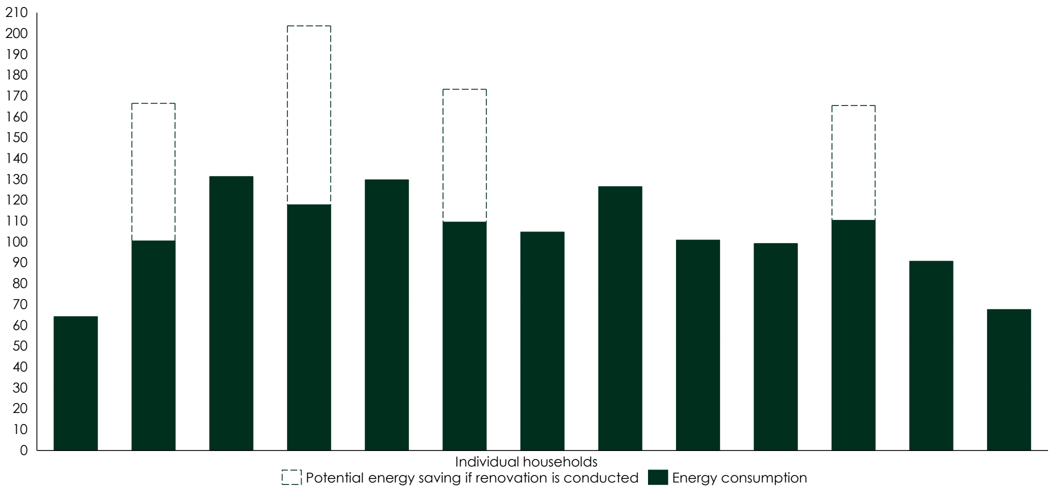
**Test results: Nordea employees**

The first test involving a bank, thorough evaluation and feedback from households, and involvement of an energy advisor was carried out in Denmark with Nordea employees. Concretely, employees settled in the Triangle Region were asked whether they would like to participate in the testing of the NEEM Core solution. We ended up getting written consent from 13 employees.[27] All employees live in Fredericia and are serviced by the district heating company, TREFOR, which has energy prices a bit above the average for Denmark (concretely, 0.67 kr. per kWh hour as of 19-09-2022).

27 See Appendix C for more detail on the design and execution of the test.

We find a large savings potential for four out of 13 households and a small savings potential for the remaining 9 households. Concretely this amounts to total energy savings of 270 kWh per $m^2$ per year, if the four households with large savings potential conducted energy renovations to reach the optimal EPC label, see Figure 37.

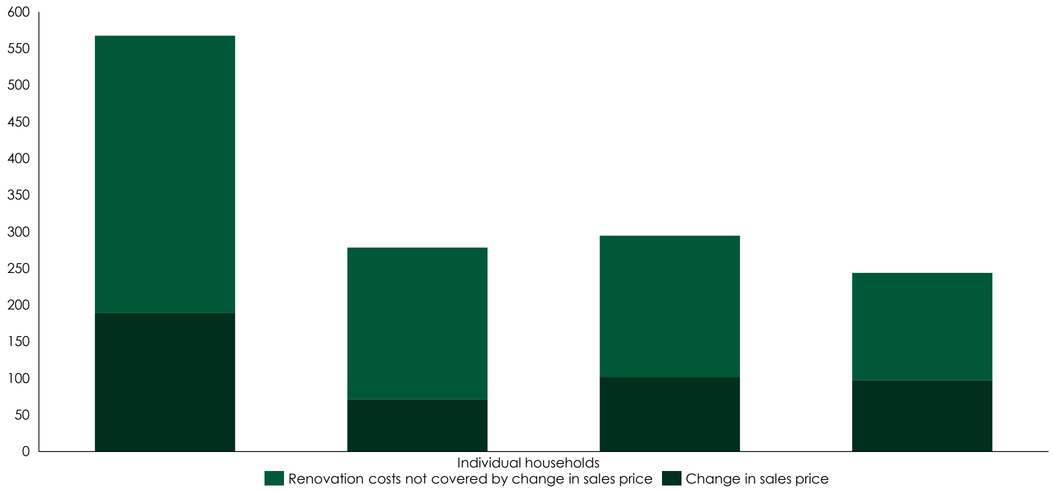
Figure 37
Nordea test: Energy efficiency and potential energy savings where renovation was profitable
kWh/sqm/year by house




Source: Copenhagen Economics renovation cost model based on CE (2015), “Do homes with better energy efficiency have higher house prices?”, and anonymised data on energy consumption and building characteristics for 103 households settled in Fredericia, Denmark.

For all houses, where we find an energy efficiency renovation to be profitable (i.e., houses 2, 4, 6, and 11), we find the initial EPC label to be D, and that the profit-maximising EPC label would be C. We estimate required investments to reach EPC label C, to be between DKK 250,000 and DKK 550,000, cf. Figure 38. The household will experience an increase in the value of their house, if they choose to sell it after having conducted the renovation – concretely we estimate it to be around 60%, i.e., roughly between DKK 100,000 and DKK 200,000.

Figure 38
Nordea test: Renovation cost for houses where renovation was profitable
Thousand DKK by house




Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 13 Nordea employees settled in Fredericia, Denmark.

We estimate the share of the heat loss for each house to be caused by respectively poor insulation and poor wind tightness, thereby giving the households an indication of where the largest energy efficiency improvements are needed. For the Nordea employees with the potential for profitable energy efficiency renovations, we find that the majority of the heat loss is caused by poor insulation see Table 19.

Table 19
Heat loss caused by respectively poor insulation and poor wind tightness

| HOUSE NUMBER | HEAT LOSS DUE TO POOR INSULATION | HEAT LOSS DUE TO POOR WIND TIGHTNESS |
|---|---|---|
| 2 | N/A | N/A |
| 4 | 72% | 28% |
| 6 | 75% | 25% |
| 11 | 81% | 19% |

Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 13 Nordea employees settled in Fredericia, Denmark.

**Test results: Jyske Bank customers**

The test results from the Nordea tests show a very flat optimisation curve, where small differences in energy prices and energy efficiency lead to large impacts on whether no energy renovation or a large energy renovation is recommended. As we do not – based on literature and talks with energy experts – believe such large jumps caused by minor adjustments to be realistic, we adjust the cost renovations model, concretely making the slope of the renovation cost curve steeper, before conducting the test with Jyske Bank customers.

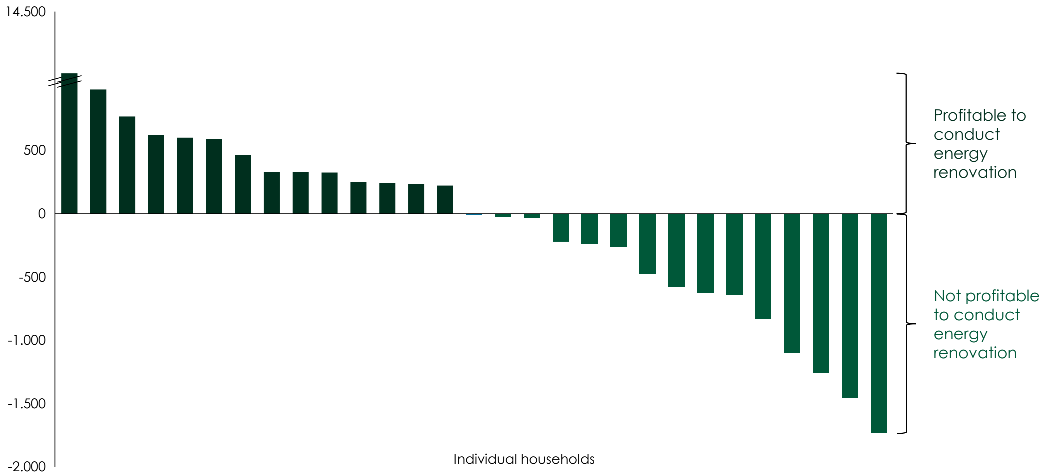
The test was done with Jyske Bank customers settled in Vejle, Fredericia, and Kolding, receiving district heat from either Fredericia Fjernvarme or TREFOR. This results in two different prices for energy consumption, with TREFOR being more expensive than Fredericia Fjernvarme, and impacts the results: the renovation costs going from one EPC label to another is the same, but the savings on the energy bill will differ depending on the utility company.

Jyske Bank did an initial screening of customers located in the Triangle Region to capture the ones with the biggest potential for energy renovations. Concretely, they looked at the building year and the house, as older buildings are more likely to have bad energy efficiency. The initial screening impacts our results: We find that it would be profitable to conduct an energy renovation for around 45% of the analysed houses, see Figure 39 – a significantly higher share than from the test on anonymised households and the Nordea test.

Advisors from Jyske Bank contacted 49 customers. From here, the customer funnel slowly narrowed:

- 46 said yes to participating in the test: quite an impressive acceptance rate of 94%.
- In 32 cases, that is, around two-thirds of the participants, all owners of the house digitally signed the consent letter.
- Of these, 29 clients received a customised one-pager. In three cases we were not able to provide results as the data quality was not high enough to get sensible results from the DTU model resulting in inaccurate results and recommendations from the renovation cost model.
- For 13 of the 29 customers receiving a one-pager, we find a large savings potential (i.e., energy renovations are profitable to conduct), which corresponds to 45% of the sample.
- For the remaining 16 out of 29, we find only a small savings potential (i.e., it is not certain that it will be profitable for the households to conduct energy renovations, and thus we do not reach out).

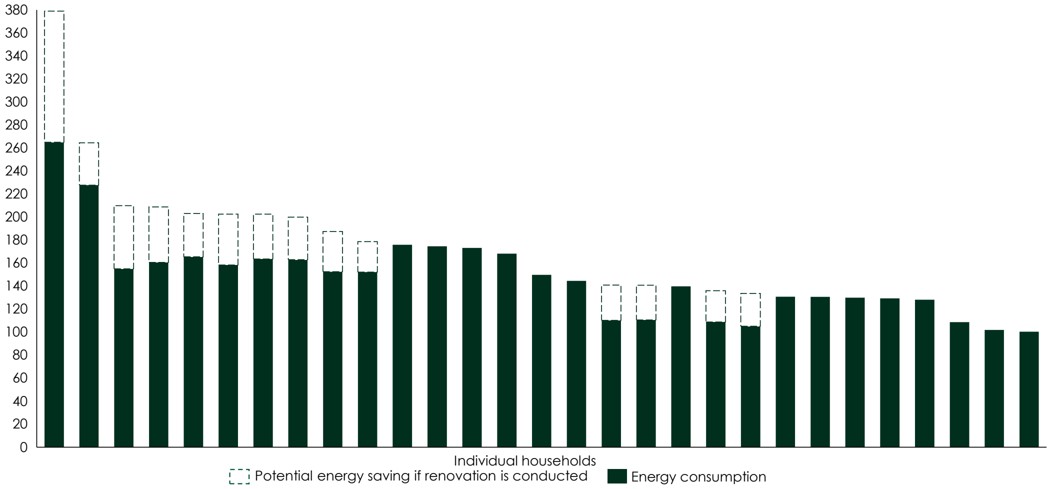
Figure 39
Jyske Bank test: Net savings for each household
DKK per year by house




Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Jyske Bank customers settled in Fredericia, Kolding and Vejle, Denmark.

We find that for the 13 houses with the highest energy consumption, energy renovations would be profitable, see Figure 40. However, we also find that it would be profitable for some houses using less energy (i.e., houses 22, 25, 27 and 29) to conduct energy renovations. This implies that having a high actual energy consumption is not the only determinant for whether a renovation is a good idea or not financially.

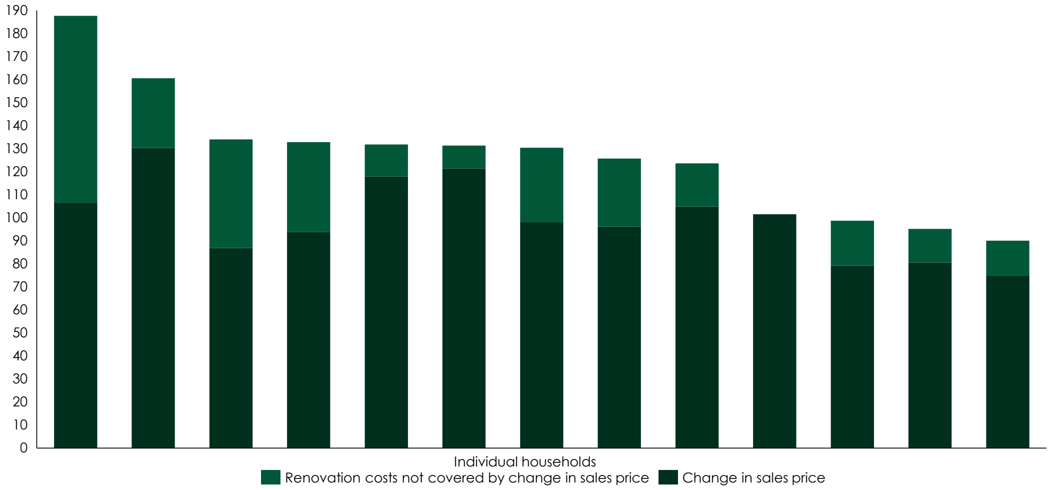
Figure 40
Jyske Bank test: Energy consumption and potential energy savings if energy renovations are conducted
kWh/sqm/year by house




Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Jyske Bank customers settled in Fredericia, Kolding and Vejle, Denmark.

The required investment cost for the energy efficiency renovations is around DKK 100,000 to DKK 250,000 in most cases, see Figure 41.

Figure 41
Jyske Bank test: Renovation cost for houses where renovation was profitable
Thousand DKK by house




Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Jyske Bank customers settled in Fredericia, Kolding and Vejle, Denmark.

All results shown above are the direct output from the renovation cost model, and not necessarily the information that has been communicated to the participating households. On top of the raw model results, we have gone through each household to quality checked the results. On the background of these cross-checks, we have made some ad-hoc changes to one-pagers sent to households, to align with the literature.

Overall, the model used in the test produced reasonable results, but with some outliers. The overall improvement area for the renovation cost model, based on the findings and learnings from the different tests carried out, is that further work is needed on the optimisation curve, which today is very flat. Here, we need to become more precise in estimating the marginal costs of conducting energy renovations. This work is part of the next steps for the NEEM Hub.

## APPROACH AND RESULTS FOR NORWAY

We take the renovation cost model developed for Denmark for given, i.e., we assume behaviours to be the same across the Nordic countries. This implies that we assume the same relationship in investment cost but not the same level of costs, renovating from one EPC label to another, and the same connection between EPC labels and sales prices for Norway as for Denmark. The overall assumptions are thus that households show the same behaviour in terms of how energy efficiency is valued.

We adjust the renovation cost model to be Norwegian-specific in the following cases:

- Changing of price level for renovation cost in 2015 from Danish to Norwegian by comparing price level indices based on actual individual consumption (EU28=100) in Norway and Denmark in 2015[28].
- Based on the development in renovation costs from 2015-2022 on the building cost index for Norway.[29]
- Based on the sales price development for houses on Norwegian data for prices on dwellings.[30]
- Used the energy cost for the relevant Norwegian utility company.

**Elvia test**

The testing of the NEEM Core Solution (and thereby renovation cost model) in Norway, happened in collaboration with Elvia, an electricity company, servicing large parts of municipalities located just north of Oslo. Here, employees were asked whether they wanted to participate in the test. We achieved written consent and access to data for 37 of Elvia's employees. Out of these:

- We retrieved robust model results and sent out one-pagers to 29 households.

---

28 Eurostat (2023): Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates.

29 Statistics Norway (2023): Construction cost index for residential buildings.

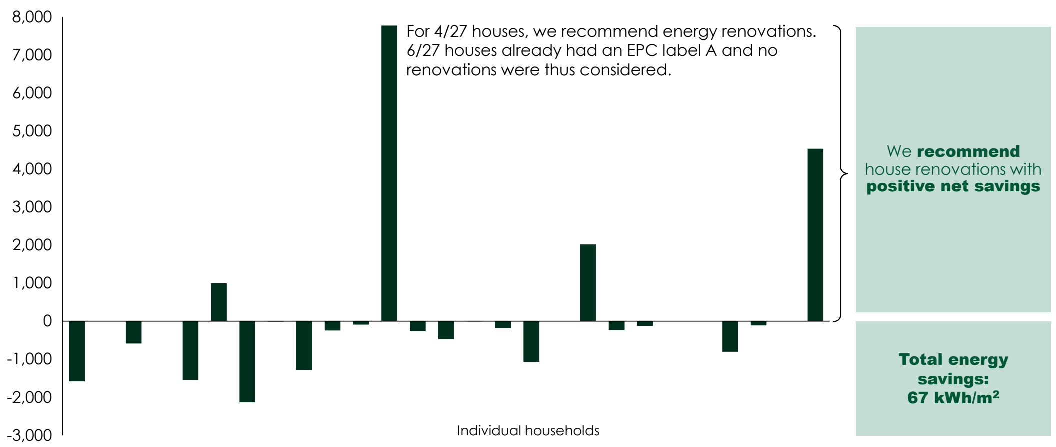
30 Statistics Norway (2023): Price for existing dwellings.

- We find that it would be profitable to conduct energy renovations for four out of the 29 analysed households.
- For the remaining 25 households, we find an energy renovation would not be profitable.

The test was based on households using electricity for heating. This meant that the DTU model originally developed to estimate primary energy demand based on district heating data, had to be adjusted (for more details see Chapter 1). The adjustment of the DTU model was a gradual process, happening ad-hoc while we ran the renovation cost model. At the first and second runs of the DTU model on the electricity data from Elvia, the renovation cost model provided unrealistic results (e.g., very big savings and thereby renovation potential for all households). During the testing phase, we were thus in close contact with DTU and further improved upon the DTU model, to make it fit for estimating primary energy demand based on electricity data as well.

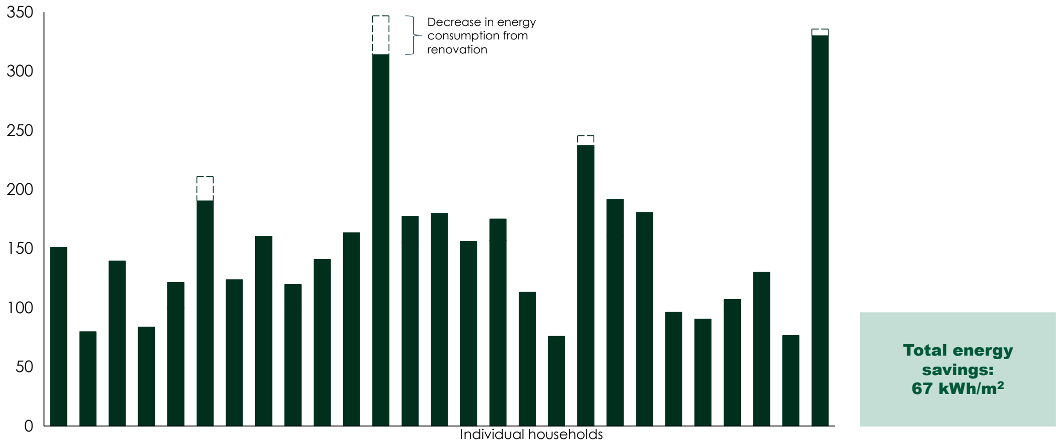
Concretely, we recommended energy renovations to four households. If the renovations were carried out, total yearly energy savings would be 67 kWh per square meter, see Figure 42 and Figure 43.

Figure 42
Elvia test: Net savings for each house if the optimal energy renovations are conducted
NOK by house




Note: Houses 2, 4, 18, 22, 23 and 26 already had an EPC label A and no renovations were thus considered.
Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Elvia employees settles outside of Oslo.

Figure 43
Elvia test: Energy consumption and potential energy savings for each house if the optimal energy renovations are conducted
kWh/sqm/year by house




Note: Houses 2, 4, 18, 22, 23 and 26 already had an EPC label A and no renovations were thus considered.
Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Elvia employees settles outside of Oslo.

## APPROACH AND RESULTS FOR SWEDEN

Our test in Sweden was carried out in collaboration with Swedbank, for households with SEOM as an electricity provider for heating. In the following explain the Swedbank test in detail.

We change the renovation cost model to be Sweden-specific, relying on the same assumptions as for the Norwegian test, i.e., that Swedish households have the same behaviour and value energy efficiency equally to Danish households. We make the model specific to Sweden by:

- Changing of price level for renovation cost in 2015 from Danish to Swedish by calculating a construction cost index as a weighted average of labour costs[31] and price level indices (EU27_2020=100)[32] in Denmark and Sweden. Weights were given as the structure of labour cost in industry, construction and services (except public administration, defence and compulsory social security)[33]. We used data from 2016 as a proxy for 2015, as labour cost levels and labour cost structure were not available for 2015.
- Based on the development in renovation costs from 2015-2022 on the building cost index for Sweden.

[31] Eurostat (2023): Labour cost levels by NACE Rev. 2 activity.
[32] Eurostat (2023): Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates [PRC_PPP_IND__custom_4684248].
[33] Eurostat (2023): Structure of labour costs by NACE Rev. 2 activity - % of the total cost.

- Based on the sales price development for houses on Swedish data for realised prices on single and double houses.[34]
- Used the energy cost for the relevant Swedish utility company.

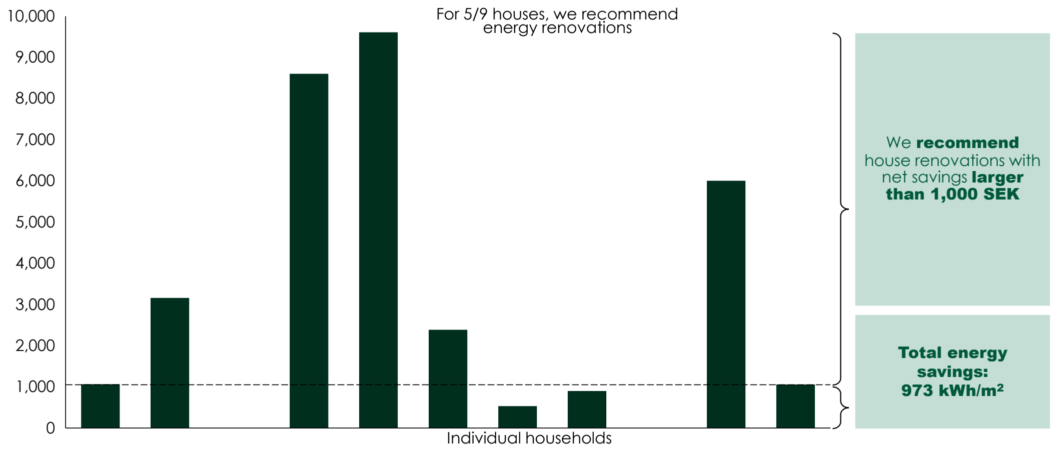
**Swedbank test**
The test was done in collaboration with Swedbank, but not all participants are necessarily customers of Swedbank. We received hourly energy consumption (electricity) data from 12 households, all living in Sollentuna, north of Stockholm and all having SEOM as their energy provider. SEOM is an electricity company that allows households to download their energy consumption data on an hourly basis in Excel, directly from their webpage. In this test, we did not need any data agreements with utility companies but could get the data needed directly from the households. Further, the households sent us their building characteristic data directly. It made a test of this size (12 households) easy but also implies it is non-scalable, as the Core principle for the NEEM Core solution has been that households should not have to do anything but say "yes" to getting their house check for energy efficiency improvements so as not to create more barriers.

Out of the 12 households from whom we received data, we find:
- Large savings potential (i.e., it is profitable to conduct an energy renovation) for five households.
- Small saving potential (i.e., it is not profitable to conduct an energy renovation) for four households.
- For three households we were not able to estimate the primary energy demand in the DTU model based on the data received (i.e., results did not converge).

[34] Svensk Mäklarstatistik (2023): Prisutveckling.

Concretely, we find that if the households, for whom it is profitably to conduct a energy efficiency renovation, does so, the total yearly energy saving per square meter would be 973 kWh, see Figure 44 and Figure 45.

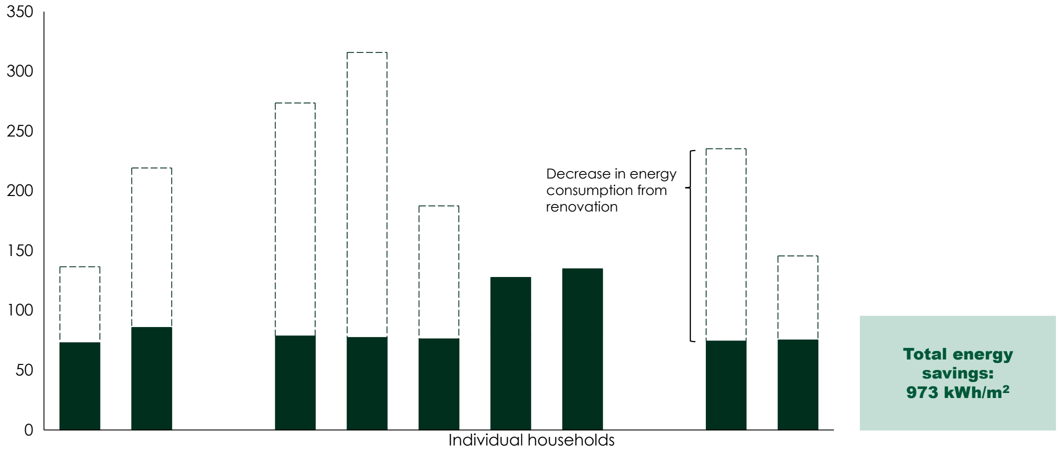
Figure 44
Swedbank test: Net savings for each house if the optimal energy renovations are conducted
SEK by house




Note: The model did not converge for houses 3 and 9, so they have been left out. We do not recommend the renovation of houses 7 and 8, as the annual net savings would be lower than SEK 1,000.

Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 29 Elvia employees settles outside of Oslo.

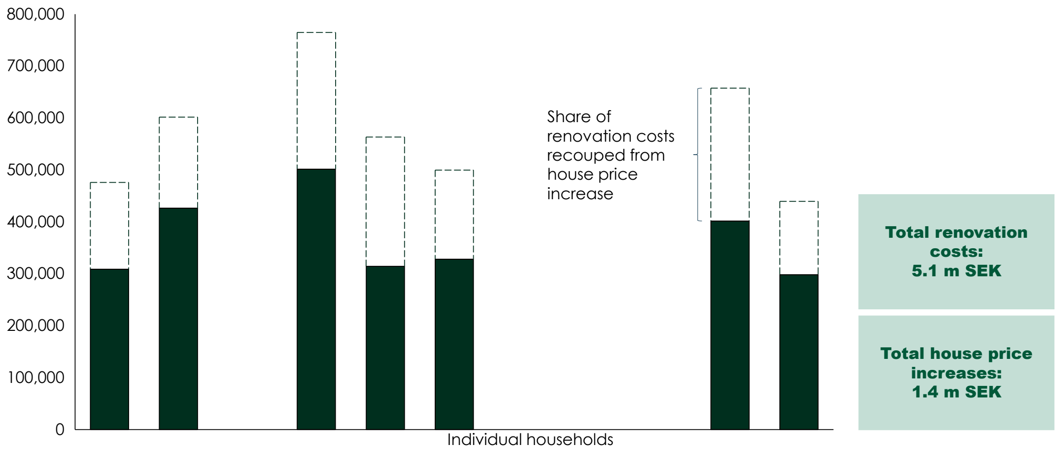
Figure 45
Swedbank test: Energy consumption and potential energy savings if optimal energy renovations are conducted
kWh/sqm/year by house




Note: The model did not converge for houses 3 and 9, so they have been left out. We do not recommend the renovation of houses 7 and 8, as the annual net savings would be lower than SEK 1,000.
Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 12 households connected to Swedbank.

The average investment cost needed to conduct the energy renovation for the five households where this would entail net savings of more than SEK 1,000 is approximately SEK 520,000, see Figure 46. Out of this, the households will get "back" approximately SEK 200,000 in increased value of their house, should they choose to sell it.

Figure 46
Swedbank test: Renovation cost for each profitable house
SEK by house




Note: The model did not converge for houses 3 and 9, so they have been left out. We do not recommend the renovation of houses 7 and 8, as the annual net savings would be lower than SEK 1,000.

Source: Copenhagen Economics renovation cost model based on CE (2015), "Do homes with better energy efficiency have higher house prices?", estimations on energy efficiency from DTU and data on energy consumption and building characteristics for 12 households connected to Swedbank.

APPENDIX C

# TECHNICAL APPENDIX: OUTREACH TO HOUSEHOLDS AND EVALUATION

## C.1 HOW FIS EFFICIENTLY REACH OUT TO CLIENTS

In this chapter, we first present insights on the main behavioural barriers, both internally in banks and externally when addressing clients. Next, we describe the pros and cons when settling on an external partner – a strategy shared by most FIs. We then present a behavioural guide on how to reach out to customers and explain how we constructed the one-pagers in the NEEM Core Solution. Finally, we present a guide on internal preparations in banks.

### UNDERSTANDING THE BEHAVIOURAL BARRIERS

A key starting point for FIs is to understand the barriers and drivers that determine the behaviours of clients and partners. Several fundamental barriers prevent or slow down the initiation of energy-efficient renovations. However, banks can play a pivotal role as a one-stop-shop, with the potential of overcoming these barriers at once.

The most important barrier, the lack of natural decision points, can be efficiently addressed by FIs since that is exactly what the NEEM Core Solution intends to do: to let the FI take the first step in proposing relevant and profitable energy-efficient renovations.

In this project, the behavioural mapping has uncovered nine behavioural barriers that need to be addressed when promoting green solutions to clients, cf. Figure 47.

In the NEEM project, the participating FIs participated in workshops to uncover and understand the behavioural barriers. The key takeaway of the workshops and presentations was the importance of addressing the barriers explicitly in outreach campaigns regardless of whether it is digital letters or verbal offers at meetings.

In Section 1.4, we present how the one-pagers developed for the FIs seek to overcome behavioural barriers.

Figure 47
Behavioural barriers limiting green actions among households

**Lack of natural decision points**

Before complexity, uncertainty and financing become potential issues, we first need the house owner to even consider renovating. Only then are other barriers relevant to address.

**Lifestyle renovations are rated**

Homeowners don't think about energy efficient renovations. They think about getting something that will improve their lifestyle, like a new kitchen or bathroom.

**Uncertainty about economic gain**

It is unclear whether and by how much the household will gain when undertaking a renovation. It is difficult to make guarantees as prices fluctuate and there are many anecdotal stories that create noise.

**Low trust and transparency**

Homeowners express a need for impartial advisors and transparency in e.g. which renovations or products would be ideal in their situation. Low trust in craftsmen prevent households from taking the first step.

**Limited information**

There is limited information about the possible solutions, suppliers, benefits and financing opportunities, creating an uncertain and flawed basis for decision-making.

**Inertia**

This barrier taps into the status quo effect - we prefer living with the current state of our house rather than making an effort and initiating changes. This applies also to homeowners who took the first step and made a plan for renovation but never acted on it.

**High perceived complexity**

There are many alternative solutions and products, many installers, many details and combinations the homeowner needs to consider. The many unknowns contribute to the high perceived complexity of the market.

**Lack of awareness**

One key takeaway is that many homeowners simply are not aware that they are in the target group. And even if they perceive energy efficient renovations as relevant for them, they do not know of the possibilities on the market.

**Invisible improvements**

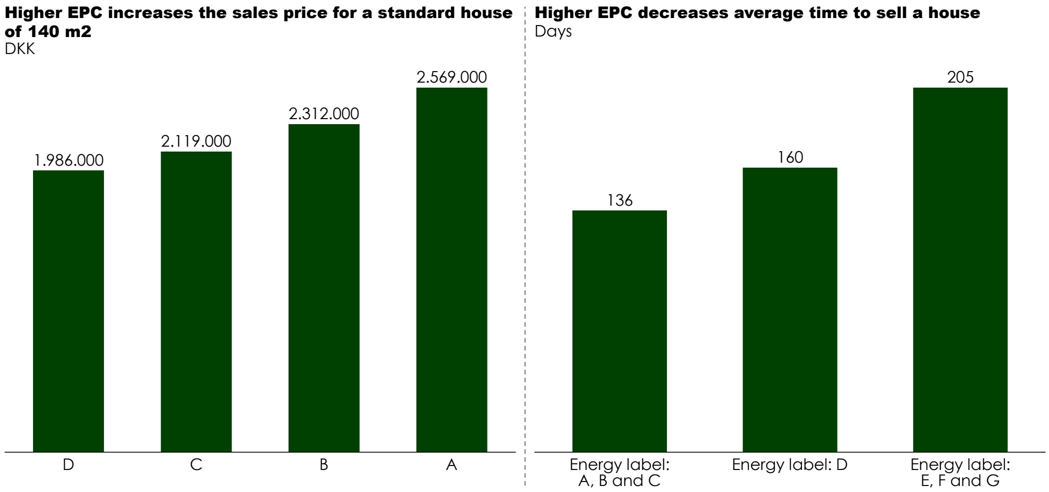
Energy-efficient renovations are often either invisible or not aesthetically pleasing. This means that the improvement lacks a tangible component that needs to be substituted from elsewhere, such as the heating bill.

Source: Behavioural Advisory

The most important non-behavioural barrier concerns profitability. If doing something green is not a solid business case, action is very unlikely. Thus, a solid business case is a requirement for achieving the attention and interest of the homeowner. Although valuable, comfort and health are not sufficiently strong drivers to compensate if no money is saved. The focus should therefore be on the best business cases, that is, the low-hanging fruits.

In addition to the economic incentive from the savings potential, the increase in sales price is a main trigger. In contrast to saving on the energy bill, most households are not aware that their house will increase in value when installing green solutions. There is great potential in sharing the fact that energy refurbishments have a significant causal effect on house price increases. Furthermore, the time it takes to sell a house decreases with higher energy labels, cf. Figure 48, panel A and panel B.

Figure 48
Higher EPC increases the sales price and decreases the average time to sell a house




Source: Copenhagen Economics

Another relevant barrier to address is the belief that the energy performance of the house is higher than it is. In Denmark, 90% of all households believe their house has an energy standard at or above average. This reveals that the savings potential is larger than perceived by most households.

However, it is not only the customers of the FI that are behaviourally constrained. The employees of the FI, in particular the banks' advisors, are also a key target group in the NEEM project. Talking about refurbishments is not core material for a bank advisor. Typically, bank advisors quickly feel out of their comfort zone when bringing heat pumps into a conversation about interest rates. The result is that refurbishments and the green agenda are not brought up at all.

In the NEEM project, this issue is handled by not requiring the bank advisors to become energy advisors – a road many other FIs have tried earlier with limited success. Instead, we would like the bank advisor to point to a certain energy partner – and thereby pass the ball without being responsible for advice in the green area. The partnership model has the potential of overcoming many of the behavioural barriers that previously have prevented advisors from bringing up the topic.

## THE RIGHT BALANCE IN PARTNERSHIP MODELS

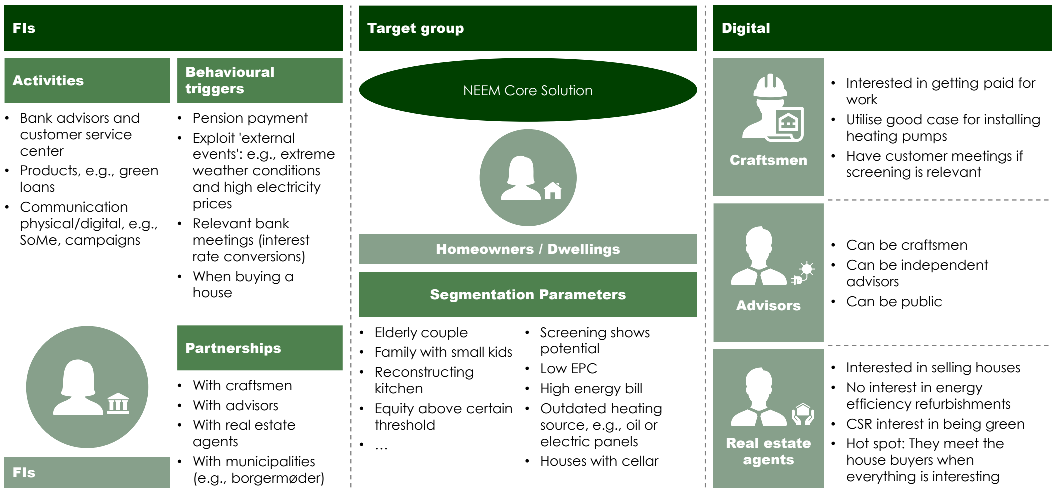
The FIs in the Nordics are at different stages of maturity in terms of fulfilling the aim of becoming a one-stop-shop for energy-efficient renovations. A common factor is the collaboration strategy: Partnering with an external provider of energy solutions.

The main goal for FIs is to identify and match the right type of clients with the right external partner that can carry out the renovations in practice. The extent to which FIs can become a one-stop-shop depends on how successfully the partnership model overcomes the barriers that prevent homeowners from acting.

Behavioural optimisation is important for both FIs, homeowners and external partners. The actions of FIs involve many behavioural aspects. For instance, whether and how the bank advisor presents green solutions depends crucially on how comfortable she feels in the situation. Which homeowners to target also depends on behavioural aspects. For instance, if the homeowners have a high energy bill, it is more likely that they will be interested in renovations as the business case is expected to be better. Using data in targeting the right type of homeowners is pivotal.

The many behavioural barriers and the different parties and interests involved are important to consider when building the optimal business model or customer journey. At workshops and in bilateral meetings, the behavioural mapping below was used to discuss how to promote the NEEM Core Solution optimally.

Figure 49
Behavioural mapping – entities, barriers and actions




Source: Behavioural Advisory

FIs do not want the task of conducting energy renovations. For FIs to become a successful one-stop-shop efficient collaboration models with third parties, e.g., energy advisors and installers, are needed.

Partnering with a company that can pick up leads and carry out energy renovations is on most FIs' agendas. The behavioural aspect of this collaboration model is that the customer journey should be behaviourally optimised and experienced as smooth and comfortable. The FI should generate the most promising leads for the external partner and the external partner should fruitfully promote the loan terms when giving the offer. The details of who does what, when, and how across FI and external parties are crucial for obtaining the best results.

In general, there are two fruitful solutions for how to select an optimal partner. The FI can team up with a commercial partner, thereby emphasising the value of having a few touchpoints: The client can buy a solution directly from the first contact point. Or the FI can team up with an energy advisor, thereby emphasising the value of recommending a trustworthy, neutral partner who cannot sell the solutions but only give recommendations. As the energy advisor has nothing to sell, the advice might cover and reflect actual needs and optimal solutions. However, whereas the commercial partner is free of charge for the FI, the energy advisor has to be paid.

The pros and cons of choosing either partner is summarised in Table 20 below.

Table 20
Pros and cons of different partner types

| | PROS | CONS |
|---|---|---|
| Commercial partners | The main advantage of commercial partners is that they can carry out installations themselves. By having a commercial entity visiting the household the household can receive an offer for the task to be solved and does not need to seek further information. In addition to this, the partnership can be made such that the only economic incentive for the commercial party is driven by potential sales to the household. | A disadvantage of choosing a commercial partner can be that they are motivated by creating profit, hence selling what they have to offer. If the commercial partner cannot fix the problem of the household, it might never be addressed as a topic. Further, if the salespeople visiting the house are too pushy or give a negative impression in another way, this will put the FI in a bad light since they were the ones to recommend them. |
| Energy advisory partners | The main advantage is that the service of having an advisor give objective input is likely perceived as valuable and trustworthy. Such a partnership will put the FI in good light and help the household make the best decisions on which green solutions to go for. | There are two main disadvantages. The first is the limitation of only giving 'advice' and not a solution that the household can accept. After a visit from the advisor, the household is left with the task of searching the market for craftsmen and engaging with a suitable partner – something which is complex and may never happen. The second is that advisors cost a fee, and this fee the FI must pay. This is a huge challenge as the pay-off must be significant to compensate for paying objective advisors for visiting houses. |

Source: Behavioural Advisory

On two occasions, the NEEM Core Solution was tested in collaboration with energy partners. The Danish FI Jyske Bank chose the commercial approach and teamed up with Bodil Energy. Bodil Energy is a service provider of heat pumps, solar panels, insulation, and home charging. Nordea Denmark chose the advisory approach and teamed up with Ewii, an energy advisory company.

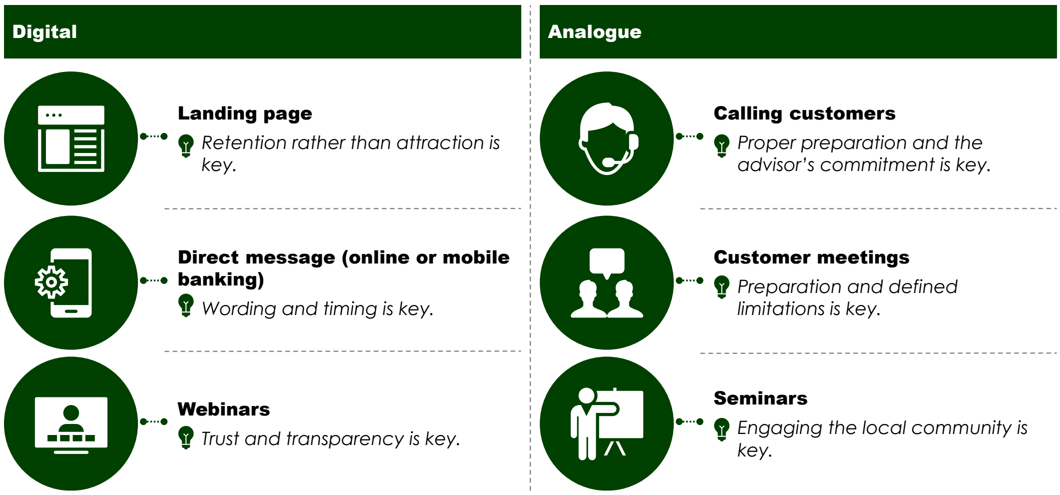
## BEHAVIOURAL GUIDE ON HOW TO REACH OUT TO CUSTOMERS

When FIs reach out to customers, they can make use of one of two approaches: Digital or analogue. The task is to match the right combination of approaches to targeted homeowners and then use behavioural guidance to maximise leads to the external partner.

The main advantage of the digital approach is low cost: It is significantly cheaper to send out direct messages to 1,000 clients compared to calling 1,000 clients or bringing energy efficiency up at 1,000 client meetings. However, the main advantage of the analogue approach is the success rate: The chance of commitment is much greater if the message is delivered in person and arguments are presented credibly in the conversation. In addition, the analogue approach may also improve the relationship to the FI, which is a goal of its own. Today, FIs apply both approaches in various ways.

In the following, we outline and explain the key behavioural aspects of the main digital and analogue communications channels.

Figure 50
Communication channels – the two main approaches




Source: Behavioural Advisory

**Digital approaches**
The digital approach largely relies on material and content produced at the FI's head office. This implies that the material must be subject to rigorous behavioural optimisation to reach a full-scale effect.

Three common digital approaches involve attracting customers to a certain landing page, sending direct messages to targeted customers, or hosting webinars. Behavioural guidance and key points are presented for each of the three approaches below.

**1. Landing page:** Retention rather than attraction is key.
When planning a renovation as a houseowner, the FI's website is not a source that one would naturally seek out in the explorative information search phase. Further, the FI's website competes with the SEO of installers, craftsmen, and manufacturers of energy-efficient solutions. Because of this, the goal is not to attract visitors and generate traffic, but that the designated landing page for energy-efficient renovations is informative, engaging and with a relevant call-to-action (CTA) to external partners. Relevant banking features such as typical loan offers, or decision tree journeys should be incorporated.

**2. Direct message (online or mobile banking)**: Wording and timing are key.
Relevant homeowners can be targeted, and a direct message can be pushed based on available segmentation data. However, it must be perceived as relevant to ensure engagement. Reaction (opening the message) and interaction (clicking the CTA) can be greatly improved by optimising the wording (e.g., playing on loss aversion is generally more effective than promising gains) and timing (following the trigger of e.g., pension payments, available grants, etc.).

**3. Webinars:** Trust and transparency are key.
Webinars are generally a big generator of leads if the information is perceived as relevant and the providers as trustworthy. With a well-structured webinar, it is possible to attract homeowners at different levels of readiness to buy. An important learning that applies to all efforts is that one of the key identified barriers of homeowners is low transparency and high uncertainty about the quality of providers. Maintaining an advisory role, even as a provider prominently featured at the webinar, is important in building transparency and trust.

Box 1 How to invite people to webinars

Most importantly: Make the headline attractive and pragmatic.

Attractiveness can be achieved by highlighting the financial incentive, e.g., the potential energy savings or the option to receive public funding.

Pragmaticism can be achieved by mentioning the date and time for the webinar, even in the headline itself. The reader might only read the headline when deciding whether this is interesting or not. Stating the date and time for the webinar creates constructive thoughts like 'Am I able to do that? Yes, I could attend. It lasts one hour; it might be ok'.

The main text should start by emphasising 'what is in it' for the reader: Most households can save X when doing Y. The text should briefly mention the topics of the webinar and should make it clear how to access the webinar. If registration is needed, it should be a large and visible button. The use of reminders to participants signing up is a must.

**Analogue approaches**
The analogue approach has great potential for initiating energy-efficient renovation journeys building on relational and conversational resources. It all comes down to the advisors and it is therefore crucial that the human factors are carefully considered and properly addressed.

A known barrier for advisors is that they fear to assume the role of energy advisor. This expectation is largely formed by some of the current material provided to advisors, often generic and lacking in guidance on 'the next step'. In a client situation, questions can lead the advisor to fill out the gaps in the material – a responsibility that they do not, and are not required to, fulfil. This may result in the advisor not choosing to engage in the energy discussion at all.

Overcoming this barrier via behavioural optimisation is achievable through sound preparation, guidance on when and how to introduce the topic and how to guide the client on what to do next. That is, making sure the advisor is comfortable in the situation and has adequate and custom materials fitting for the specific homeowner and their situation.

Three common analogue approaches involve cold-calling customers, bringing up the topic at certain customer meetings and hosting physical seminars. Behavioural guidance and key points are presented for each of the three approaches below.

**Calling customers:** Proper preparation and the advisor's commitment are key. Calling customers is time-consuming for advisors and value needs to be balanced for both parties. The advisor has not only to buy in on the purpose of the call, but also feel comfortable talking about green renovations, and knowing how to handle follow-up questions and positive responses – that is, knowing what material to provide to the homeowner and how to easily refer the homeowner to the external partner. Involvement and self-initiatives during the preparation phase can strengthen the advisor's commitment as can making calls a social activity at the office.

In the NEEM Core Solution calling customers was used in some of the tests. This created three key decision points in the customer journey, where we would like the client to turn in the right direction and continue the journey.

First, in the opening conversation with the bank advisor we need the client to say 'Yes, I am interested in having my house energy screened'. Second, when reading the one-pager for households with large savings potential we need the client to do the requested action, e.g., call an energy advisor or reply to the message. Third, after the visit of the energy advisor, we need the client to take action a final time and carry out the renovation.

In the box below, we present inspiration on how to steer the call with the purpose of the NEEM Core Solution.

Box 2 How to steer the conversation

Here is inspiration for the customer dialogue that can help the advisor overcome behavioural barriers in the opening step: convincing the client to accept a digital energy screening.

In the opening phase, we recommend asking the customer a broad question related to the topic. Two examples:

These days you can't open the paper without reading something about energy prices. Is that something that affects you as well?
We see that a lot of our customers have recently done some things in their homes that they've been considering for a while, everything from painting to major projects. Do you have any plans for your house too?

Once the topic of energy prices or house alterations is brought up, one can easily ask further questions about the topic. Three examples:

How do you heat the house today?
Are you happy with it (the heating of the house)?
Do you know what you pay for heating? (Many people don't know.)

Now that the advisor has learned the status of the client's heating installations, it is time to open the door for changes. Of course, these need to be tailored to the context. If the energy source is oil/gas/pellet/half-lit the advisor can safely highlight several good arguments for acting. The conversation could go like this:

'Have you considered energy renovation? Money can often be saved on heating bills by switching heating, particularly in your case, I would say. With energy renovation, you can also expect the home's energy rating to move up one or two notches and the home's $CO_2$ consumption on heating to be at least halved. Is that something you might consider if there is money to be saved?'

If in need of arguments for why switching is beneficial the advisor can reference, why clients in similar situations choose to act:

We find that people have many different reasons for switching:
A significantly lower heating bill.
Minimal maintenance and hassle.
Increase home value (buyer looks at energy labels and heating consumption).
A significantly lower climate impact and better energy rating (1-2 levels).
Better indoor climate.

The final and most important question, which can be posed as soon as the advisor would like, is: 'Would you be interested in finding out if it would make sense for you?'.

If the customer is interested, the advisor can continue like this: 'We have heard from several customers that they are considering switching but are unsure if it is worthwhile and which option is best for them. After all, I'm no expert on energy and heating sources. We work with 'NAME OF ENERGY PARTNER', who offer a free energy screening of your house. This will give you an accurate estimate of whether it would make sense for you to renovate or not and how much can save annually. Would you like a free energy screening, to begin with?'

**Customer meetings:** Preparation and defined limitations are key.
A significant barrier for the advisor is a perceived lack of knowledge on the subject. When an advisor is handed the task of discussing energy renovations at a

customer meeting – the lack of connection between their role and the task, amplified by fear of acting as an energy advisor, means they rather not open for the discussion at all.

As with calling customers, it is essential that the advisor has been properly prepared and that the limitations of their role have been defined, that is, they are an advisor on financial matters, not energy-efficient renovation, and they are only responsible for knowing how to refer to material or external partners for answers, and not knowing the answers themselves.

Key behavioural concepts on this matter are touchpoints and hot spots. The advisor should bring up energy renovations when the renovation is already being discussed (touchpoint) or would be natural to be discussed (hot spot). Table **21** presents real-life examples from a FI on when to discuss energy renovations. The table presents the trigger and the according solution to be presented by the advisor. The decision tree makes it easy to know when to propose what.

Table 21
Triggers and corresponding solutions

| TRIGGER | CHANGE IN HOUSEHOLDS' COSTS | HOUSEHOLD CONSIDERATION | POSSIBLE ADVISOR ACTIONS | [HEADING] | [HEA |
|---|---|---|---|---|---|
| Overdraft on budget account – Rising energy prices | Higher costs for heating and electricity. | They usually don't notice | Fix the problem. Suggest heat pump and/or solar cells | | |
| Buying an electric car/having an electric car/considering an electric car for the next car | Increased electricity consumption | Wanting lower car costs | Suggest solar cells, batteries, and charging stands | | |
| Taking a new loan/conversion | The client has to do it anyway | Is there something that can be advantageously co-financed, which reduces the current costs for energy/increases the value of the house and possibly can pay the loan | Suggest heat pump, solar cells, and battery | | |
| Buying a house | The client is already doing something in the house | Is there something that can be done advantageously when you have craftsmen in the house, and which can be co-financed, which reduces the current expenditure on energy and can finance other projects you have to start with | Suggest heat pump, solar cells, and charging stand | | |
| Increased electricity consumption<br>- Staying at home more (working more at home, self-employed, maternity leave)<br>- Having children / more children | Higher costs for heating and electricity | To a greater extent being able to produce electricity yourself for the increased consumption | Suggest solar cells and battery | | |
| Must switch heating source | Save money on heating; the heat pump uses electricity | As the heat pump uses electricity, it is worth looking into producing it yourself | Suggest heat pump, solar cells and battery | | |
| New roof | When you have to change the roof anyway | Roof with built-in solar cells or panels on a new roof | Suggest solar cells and battery | | |

Source: Behavioural Advisory

**Seminars:** *Engaging the local community is key.*
Seminars can be a powerful arena for engaging the local community, creating awareness and often shifting the gathered homeowners from an initial search phase to actual decision-making, all within a couple of hours. Gathering homeowners, an impartial expert, one or more suppliers, representatives from the municipality and the FI, at a seminar present an opportunity of overcoming multiple barriers at once. Breaking down the silos creates transparency, trustworthiness,

and a feeling of exploring the market advised by impartial experts and being backed by financing opportunities and municipal support.

## GUIDE ON HOW TO MAKE ONE-PAGERS

In the NEEM Core Solution model tested by two FIs in Denmark, customers were called and asked if they would like a free and objective digital energy screening. If they said yes, they would receive a one-pager developed by the NEEM Consortium.

In total, we have tested four versions of the one-pagers. They differ across test conditions but share key characteristics. Of the two versions, one is for clients with a large savings potential, and one is for clients with a small savings potential.

In the following, we explain the key behavioural aspects of the one-pagers. The aspects that were different due to FI considerations are presented and discussed in Chapter C.2.

**The behavioural reasoning of the design – large savings potential**

The starting point of developing the one-pagers is based on the fact that humans are rationally bounded. We like to think of ourselves as rational, but the reality is that we sometimes make decisions based on cognitive biases and heuristics (rules of thumb). This makes us behave systematically and predictably wrong compared to rational standards. In behavioural science, this is explained by dual process theory, in which the system creates systematic errors.

To correct for these, the one-pagers are designed to make use of six key principles in behavioural communication:

1. Make it easy (e.g., easy-to-understand language, use of highlighted text).
2. Make it salient (e.g., coloured box and coloured text, large green box).
3. Make it intuitive (e.g., pictograms used to emphasise the meaning of benefits).
4. Make it actionable (e.g., clear step-guide instructions on what to do next).
5. Make it social (e.g., private names are used as much as possible).
6. Make it attractive (e.g., message highlights benefits of acting).

Below we have illustrated the one-pager for large savings potential developed for the FI Jyske Bank.

Figure 51
The first page of the one-pager: Large savings potential, Jyske Bank Denmark

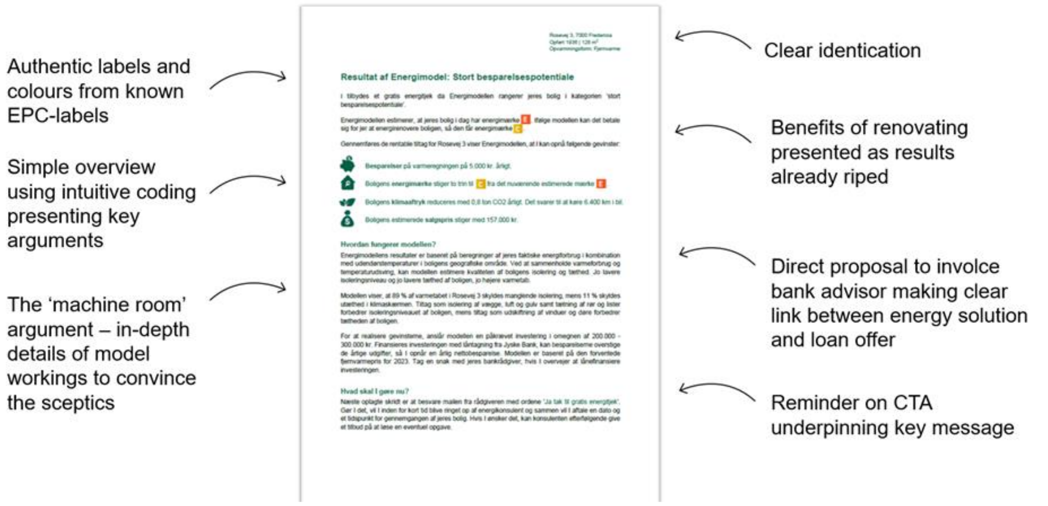

Source: Behavioural Advisory

The one-pager, which is actually a two-pager, has one purpose: To get the client to reply and accept to be contacted by the energy partner. That is the most important goal of the one-pager.

Therefore, the first page highlights this proposal in a salient green box. The box is presented as quickly as possible. The headline highlights the same key message, so it is repeated within half a page. The first couple of sentences are therefore introductory words explaining that the house belongs to the category 'large savings potential' and that the household can get a free energy inspection.

At the top, the address is shown making the identification clear. At the bottom, a personal signature is moved since it creates more trust.

Figure 52
The second page of the one-pager: Large savings potential, Jyske Bank Denmark




Source: Behavioural Advisory

Page two of the one-pager presents arguments credibly documenting the savings potential and the workings of the energy model. At the top, authentic labels and colours are used from the EPC labels to show they are actual EPC predictions. The benefit of renovating is written so that it seems the savings are already reaped if only one increases the energy label on the mark. Intuitive coding is used to make the key arguments easy to understand. Here we present the yearly savings potential in monetary terms, the $CO_2$ savings potential, the potential increase in energy label and the estimated increase in house price when renovating.

The middle of the page presents the reader with in-depth details of the workings of the model. The purpose is to convince the sceptics that the energy model is solid. In the same section, we present a direct proposal to involve the bank advisor thereby making a clear link between renovation and loan offer.

The final words of the one-pager repeat the main message: Reply to this message to accept being contacted by a relevant energy partner.

**The behavioural reasoning of the design – small savings potential**
Below we have illustrated the one-pager for small savings potential developed for Jyske Bank.

Figure 53
One-pager: Small savings potential, Jyske Bank Denmark

Anemonevej 3, 7000 Fredericia
Opført 1976 | 165 m²
Opvarmningsform: Fjernvarme

## Resultat af Energimodel: Din bolig har en god energitilstand

Kære Anna og Jens

Vores Energimodel[1] viser, at jeres bolig tilhører kategorien *lille besparelsespotentiale*. Det betyder, at jeres bolig har en god energitilstand – hvad angår både tæthed og isolering – og at der derfor ikke er store besparelser at hente på varmeregningen.

Energimodellen anslår boligen på adressen Anemonevej 3 til at have energimærket C

Umiddelbart finder vi, at besparelserne på varmeregningen ikke alene vil kunne finansiere energirenovering, der bringer energimærket op til energimærke B.

Der er dog andre gode grunde til at renovere boligen end besparelser på varmeregningen. Energiforbedringer kan fx øge komforten og mindske træk og kolde flader. Et højere energimærke øger desuden værdien af boligen, og dermed også salgsprisen når boligen en dag skal sælges. Konkret viser resultater fra tidligere studier, at en forbedring fra energimærke C til energimærke B i gennemsnit øger salgsprisen med 94.000 kr.

Tak fordi I gav os samtykke til at anvende jeres boligs energiforbrug fra enten Trefor eller Fredericia Fjernvarme og beregne besparelsespotentialet for jeres bolig.

Med venlig hilsen

Jonas Bjarke Jensen
Managing Economist, Copenhagen Economics (Jyske Bank-samarbejdspartner)

[1] Energimodellen er et beregningsværktøj udarbejdet af DTU, Copenhagen Economics og en række andre Jyske Bank-samarbejdspartnere. Ved at sammenholde jeres faktiske energiforbrug med vejrdata i samme periode, giver modellen et præcist billede af boligens energitilstand og besparelsespotentiale.

Source: Behavioural Advisory

The purpose of this one-pager is to end the customer journey leaving the client satisfied with the effort and having a positive impression of the FI initiative. Though the one-pager does not offer a free house visit it does give some interesting information to the client.

First, it informs the client of which energy label the energy model estimates for the household. In Figure 53, it is label C. As only around one-third of all single-family houses have an energy label, this information is interesting to a vast share of households.

Second, it tells the client that the energy performance of the house is good. This information is often perceived as relevant and interesting. It reassures the client that they do not need to spend more time thinking about renovation options but can focus on other areas.

Third and finally, the one-pager for small savings potential presents an estimate of the increase in house price that would happen, if the house should be renovated to one energy label higher, in this energy label B. This is new information for all households.

**Guide on internal preparations in banks**

The FIs need to address several barriers to utilise the opportunity of the NEEM Core Solution as well as other energy efficiency activities.

First, it is a challenge that initiatives such as the NEEM Core Solution requires cross-unit alignment. Cross-unit alignment is a prerequisite for the implementation which is a challenge since different units within the bank have different priorities and objectives. This often creates ambiguity in the role played by the FIs in the ecosystem of the collaboration model.

Second, there is to some extent a lack of priority on lifting the green agenda as well lack of ownership and connection to the strategic agenda in the business strategy. Many FIs are still somewhat immature in this field internally to fully explore the potential of the NEEM Hub and other green solutions.

Third, data approaches – such as the NEEM Core Solution – are challenging due to GDPR restrictions. The FI need a setup where bottlenecks are efficiently removed before initiating a process that will not work in practice. In relation to this, an internal barrier is typically the availability of resources in IT development.

When testing the NEEM Core Solution, we had to develop a consent document and ask participants to fill out the document to gather energy data for their household. It is a focal point to avoid such friction points in scaled versions of the test. Appendix 1 presents the consent document used by FI when testing the NEEM Core Solution.

The NEEM Hub collaboration has yielded learnings that they and other FIs can now benefit from. Here are key takeaways in terms of internal preparations for approaches such as the NEEM Core Solution.

**GDPR and consent.** It is pivotal that consent is built into the process in an easy or even automatic way, so it does not become a barrier in itself. In the Hemma solution, the customer gave consent when applying the solution as an initial step. Seconds later, the customer had the result. This is an example of an easy way.

**Ownership and cross-unit collaboration.** The FI should establish clear goals and objectives for the implementation process and ensure that all units are aligned with these goals. For this process, a distinct collaboration between business-oriented employees and product owners is crucial.

## C.2 RESULTS FROM TESTING THE NEEM CORE SOLUTION

The NEEM Core Solution is tested across Denmark, Norway and Sweden. Though the customer journey differs across countries, financial institutions and energy partners, the approach consists of the same main steps.

In this chapter, we first explain the test design used to evaluate the NEEM Core Solution (2.1). We then present the results from testing the NEEM Core Solution in collaboration with Nordea Denmark (2.2). Next, we present the results from testing in collaboration with Jyske Bank (2.3) and finally, we present the results from testing with Elvia and Swedbank (2.4).

For each test, we cover as many key dimensions as possible, e.g., quantitative conversion results, qualitative feedback from clients and the final evaluation from the financial institutions.

### TEST DESIGN USED IN THE NEEM CORE SOLUTION

Five key aspects are tested when testing the NEEM Core Solution. For the financial institutions, the success criteria are that a high share of clients…

1. … give consent to retrieve data
2. … have a large savings potential
3. … act when receiving the one-pager
4. … renovate as a result of the initiative
5. … perceive the FI initiative as positive

Some of these aspects can be investigated by looking at the quantitative measures of the different steps in the customer journey. For instance, we will easily be able to quantify the share that gives consent to retrieve data, the share that has a large savings potential and the share that acts when receiving the one-pager.

However, whether clients renovate or not is more difficult to know. We can ask them in a questionnaire after the test, but in this case, the time to act is limited, and planning and executing on a renovation may easily take months. As the project does not permit us to ask after six months, we must therefore also ask about their plans and their assessment of the likelihood that they will renovate within a year or so.

Regarding the positive perception of the financial institution initiative, we may ask the opinion of the test participants. As conversations allow a more in-depth understanding of the considerations compared to a few written sentences, we would like to interview participants on the phone.

In addition to these client-oriented success criteria, the experimental design must allow us to test whether the NEEM Core Solution proves a valid tool for financial institutions. Crucial aspects are here the resources needed to apply the model and the accuracy of the model itself in predicting houses with large savings potential.

In the following, we present the results of the NEEM Core Solution.

## TEST RESULTS – NORDEA DENMARK

In collaboration with the Danish financial institution, Nordea Denmark, we tested the NEEM Core Solution. Below we present first the customer journey, then the results and finally the feedback from the bank.

**The Nordea Denmark customer journey**

Below we have illustrated the customer journey for Nordea, Denmark, in which employees are contacted by phone and clients with large savings potential are offered a free energy visit by a commercial partner. The complete journey consists of five steps explained in the following.

Figure 54
Customer journey of the NEEM Core Solution – Nordea Denmark

| 1 Jyske Bank calls clients | 2 Clients sign consent letter | 3 Clients receive one-pagers | 4 Clients recieve house visit | 5 NEEM collects feedback |
|---|---|---|---|---|
| • Jyske Bank calls clients and asks if they would like a free energy screening<br>• Clients are pre-selected based on geography and house and client characteristics | • Jyske Bank sends the consent forms to the clients<br>• Clients log in and sign digitally the consent form | • Clients receive customised one-pagers with estimated energy label and savings potential<br>• Clients with large savings potential are offered a free, physical energy check | • Clients who accept a free house inspection are contacted by Bodil Energy<br>• A partner of Bodil Energy visits the house, gives recommendation and makes an offer if relevant | • NEEM sends questionnaire to all clients participating in the pilot<br>• Clients who accept are interviewed in depth |

Source: Behavioural Advisory

In step 1, the NEEM Consortium carefully planned the test in collaboration with Nordea headquarters, and colleagues in branches in a certain geographical area (Trekantsområdet) were asked to participate in the test. The pitch was to help Nordea test an 'Energy model' that could be used for clients at a later stage.

In step 2, participating clients filled out a consent form which was sent to the NEEM Consortium. The NEEM Consortium collected data from TREFOR and Fredericia Fjernvarme and produced customised one-pagers showcasing the potential energy savings of the households.

In step 3, the employees of Nordea Denmark received the one-pagers and employees with large savings potential were encouraged to call an objective energy advisor and arrange a house visit.

In step 4, the households with large savings potential could get a free house visit. At the visit, the energy advisor would give recommendations to the household, but not give concrete offers as the actor was non-commercial.

In step 5, the NEEM Consortium sent questionnaires to all the employees participating in the test. Employees could voluntarily accept to be interviewed in-depth on the phone by NEEM.

**The Nordea Denmark test results**
In the following, we present results from testing the NEEM Core Solution in collaboration with Nordea Denmark. The results are divided into two sections: quantitative and qualitative results.

In sum, five main conclusions should be highlighted:

1. The NEEM Core Solution model finds that 31% of households (employee sample) have a large savings potential. These could be offered a free house inspection or be directed to a commercial partner.

2. Among households with large savings potential offered a free house inspection, 50% act and call the advisor.

3. Evaluation results show that five out of six (83%) households think the overall experience from the Nordea initiative was ‘good’ or ‘very good’.

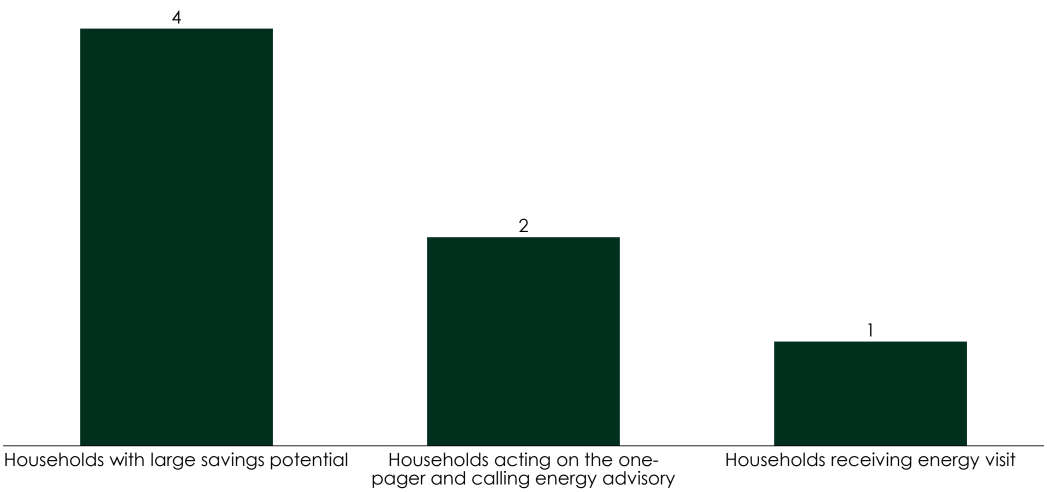
4. In total, 2 out of 3 (67%) households think the digital energy screening is ‘good’ or ‘very good’. No one thinks it is ‘bad’ or ‘very bad’.

5. All respondents think it is positive if Nordea engages in energy initiatives. All respondents with small savings potential agree with the one-pager’s conclusion.

**Quantitative analysis of the customer journey**

Among the 13 Nordea employees participating in the test, four were estimated to have a large savings potential corresponding to 31% as shown in Figure 55. Among these four households, two reacted to receiving the one-pager and called the number on the one-pager thereby contacting the energy advisor (50%). One of them received a house visit (50%). Due to illness, the second house visit was cancelled.

Figure 55
Final steps of the customer journey for clients with large savings potential

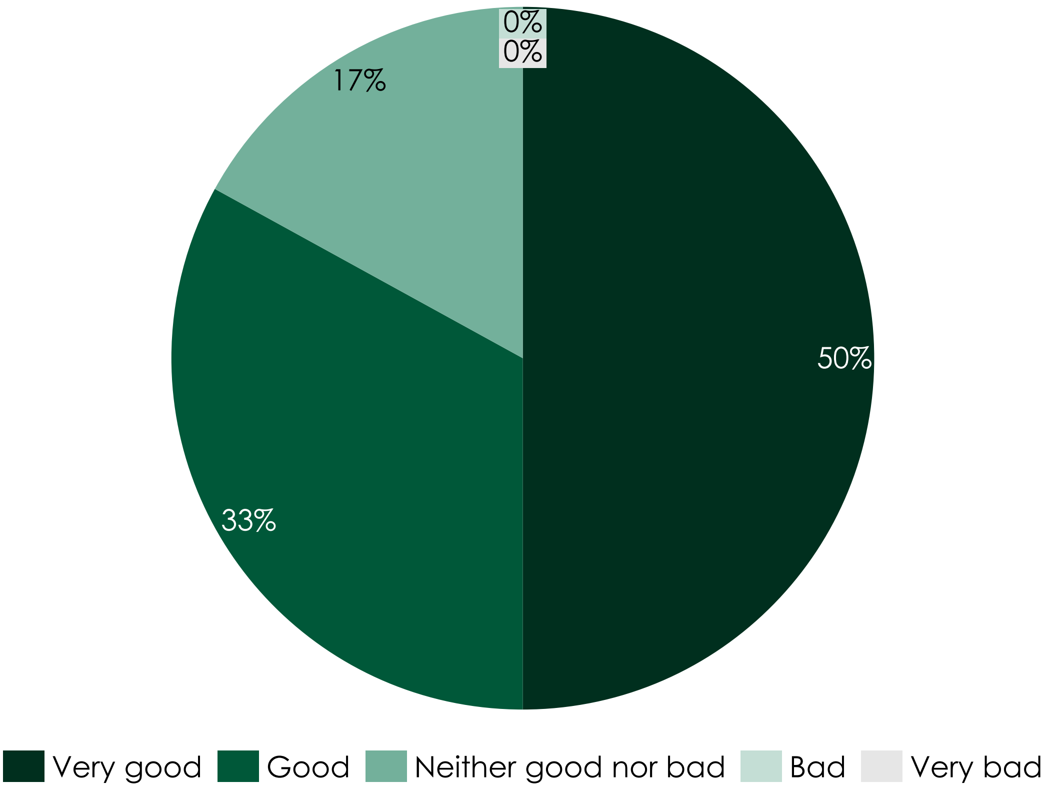



Source: Behavioural Advisory

## QUALITATIVE ANALYSIS OF THE CUSTOMER JOURNEY

The first conclusion from the survey is that five out of six (83%) think the initiative from Nordea is ‘good’ or ‘very good’ as shown in Figure 56. No one thinks it is ‘bad’ or ‘very bad’.

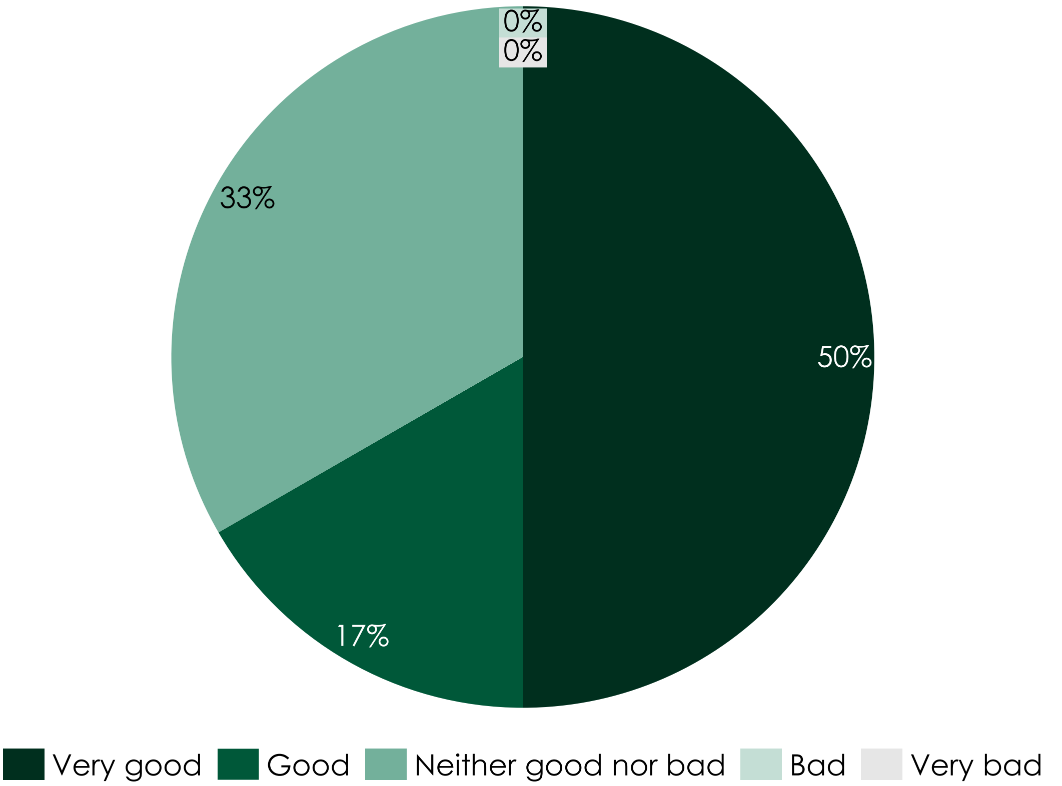
Figure 56
What is your overall experience of the offer from the financial institution for energy screening of your home?




Source: Behavioural Advisory

The second takeaway from the client feedback is that four out of six (67%) think the one-pager from Nordea is ‘good’ or ‘very good’, shown in Figure 57. Again, no one thinks it is ‘bad’ or ‘very bad’.

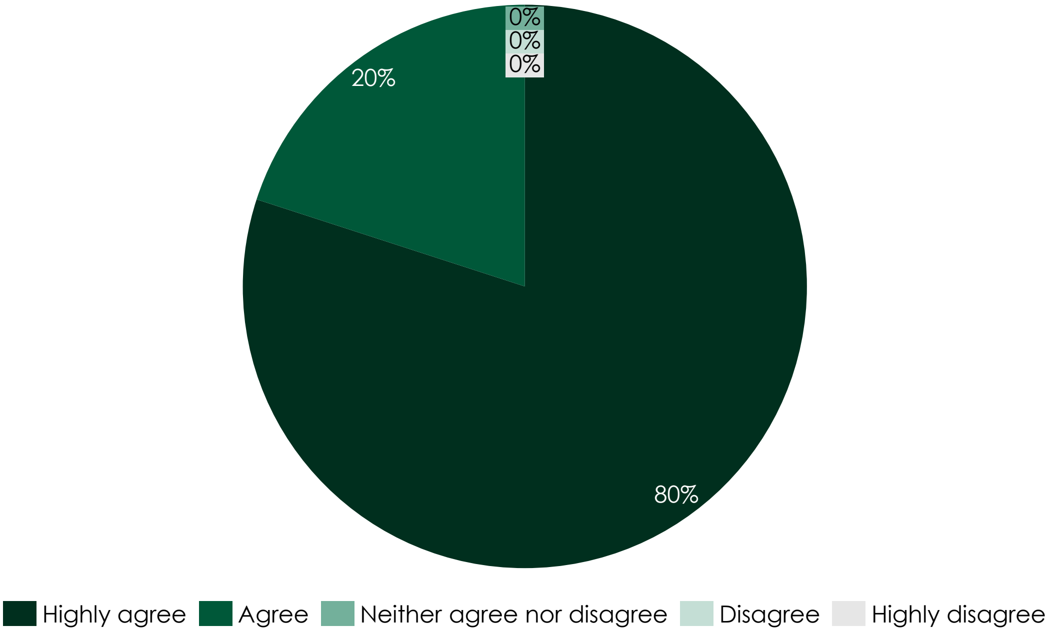
Figure 57
What is your experience of the digital screening – i.e., the PDF you were sent by the bank advisor?




Source: Behavioural Advisory

The third takeaway is that the one-pager for small savings is quite precise: No one believes the conclusion is wrong and 80% 'highly agree' that it might not be profitable to renovate, shown in **Figure 58**.

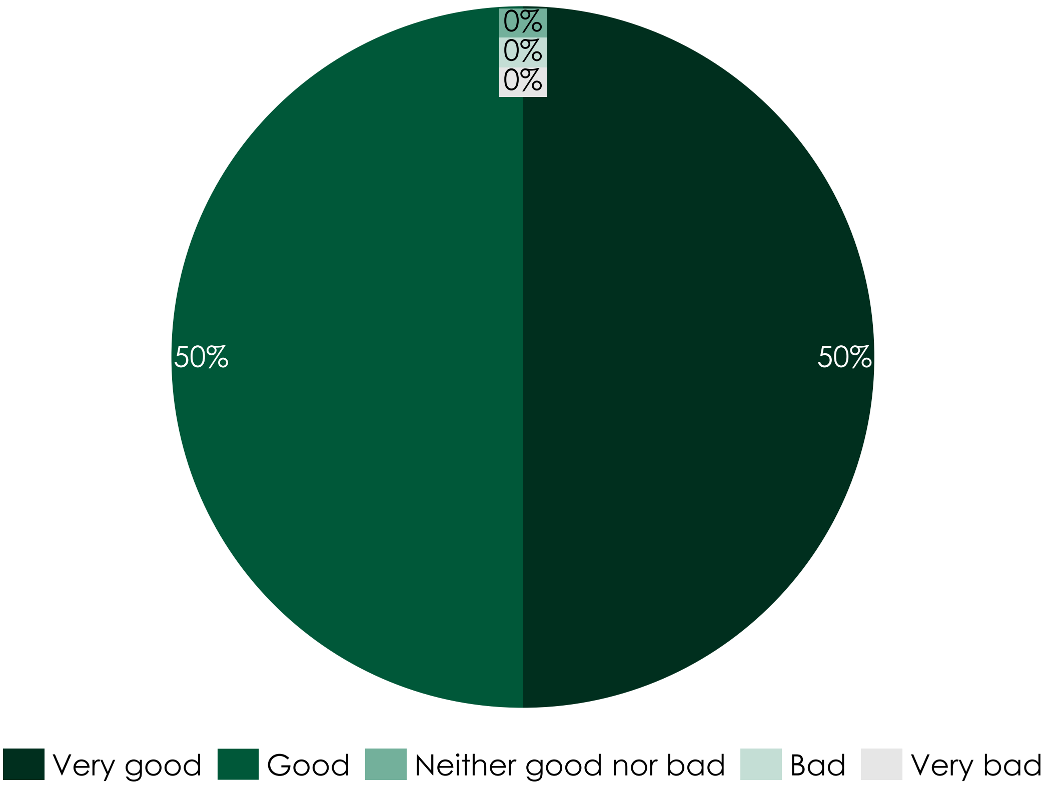
Figure 58
The result of the digital screening showed that your home has a high energy performance. The energy model estimates that the savings on heating bills will not be large enough to cover any energy renovation. To what extent do you agree that it might not be a profitable for you to renovate?




Source: Behavioural Advisory

Finally, the fourth conclusion is that everyone thinks it is positive if Nordea engages in energy initiatives. In total, six out of 6 (100%) think it is ‘good’ or ‘very good’ if Nordea does so more often in the future, as shown in Figure 59.

Figure 59
What do you think about your bank doing this type of initiative related to the energy renovation of your home?




Source: Behavioural Advisory

**Evaluation from Nordea Denmark**
The overall perception of the NEEM Core Solution was positive:

> "A good and pragmatic solution to tackle some of the barriers for homeowners to transition to greener state, e.g., lack of awareness and decision point. Innovative solution that works with several angles for the analysis (e.g., adding weather data) to be more precise to that specific building and by that avoiding to generic advice to the customer."

Representative, Nordea Denmark headquarters

The feedback from Nordea emphasised the importance and value of behavioural analysis:

> "In the foundation work for the NEEM Core Solution; great work identifying and making the barriers tangible and understandable."

Representative, Nordea Denmark headquarters

The answers to the most important learnings from participating in the NEEM Hub point to understanding households' barriers and knowledge of relevant entities to build long-lasting partnerships with:

"Insights to the importance and types of barriers in energy efficiency improvements for homeowners. Insights and connections to ongoing activities in this field, e.g., Hemma, Bodil Energy, Watts, paving the way for further collaboration to resolve the challenges in this field."

Nordea Denmark is highly active in the green agenda, having a strong collaboration with the energy solution provider Bodil Energy. Nordea Denmark believes the NEEM Core Solution is a good fit together with their general ambitions within the green transition as an enabler for presenting insights to homeowners.

Nordea Denmark is open to NEEM Core Solution playing a role in future initiatives and the financial institutions are at this stage in the process of exploring how it can play a role and which solutions they should prioritise to develop and/or partner up on.

Concretely, the next steps for Nordea Denmark within the green agenda are very much in line with the aim of the NEEM Hub:

- Expand the product offering to cover more green products incentivising the customers (e.g., with discounts).
- Continue building the data foundation for both reporting and customer insights.
- Test scalable solutions to provide insights to homeowners.
- Partner up in relevant areas to complement our data, products etc to tackle the homeowners' barriers.

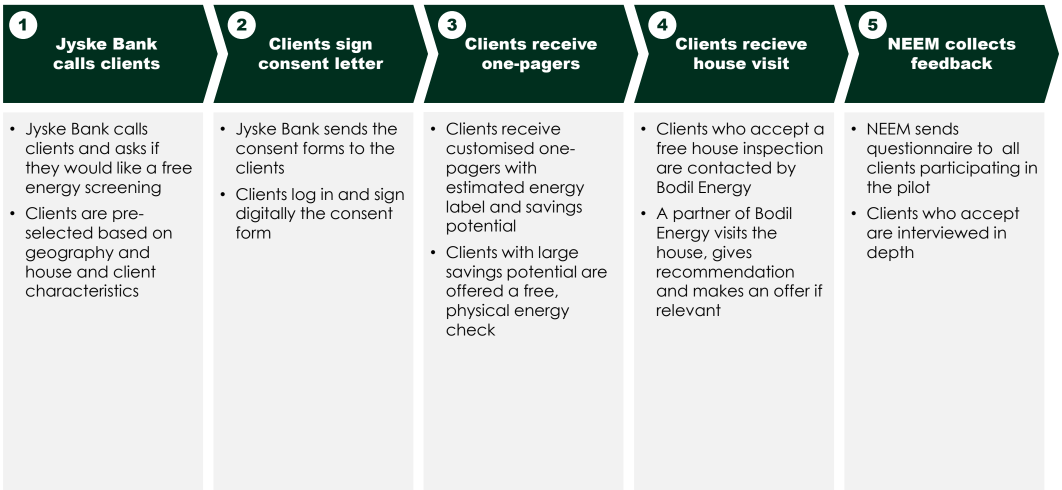
## TEST RESULTS – JYSKE BANK

In collaboration with the Danish financial institution, Jyske Bank, we tested the NEEM Core Solution in the autumn of 2022. Below we present the process from reaching out to clients to finalising the test.

**The Jyske Bank customer journey**

Below we have illustrated the customer journey for Jyske Bank, Denmark, in which clients are contacted by phone and clients with large savings potential are offered a free energy visit by a commercial partner. The complete journey consists of five steps as shown in Figure 60 and explained in the following.

Figure 60
Customer journey of the NEEM Core Solution

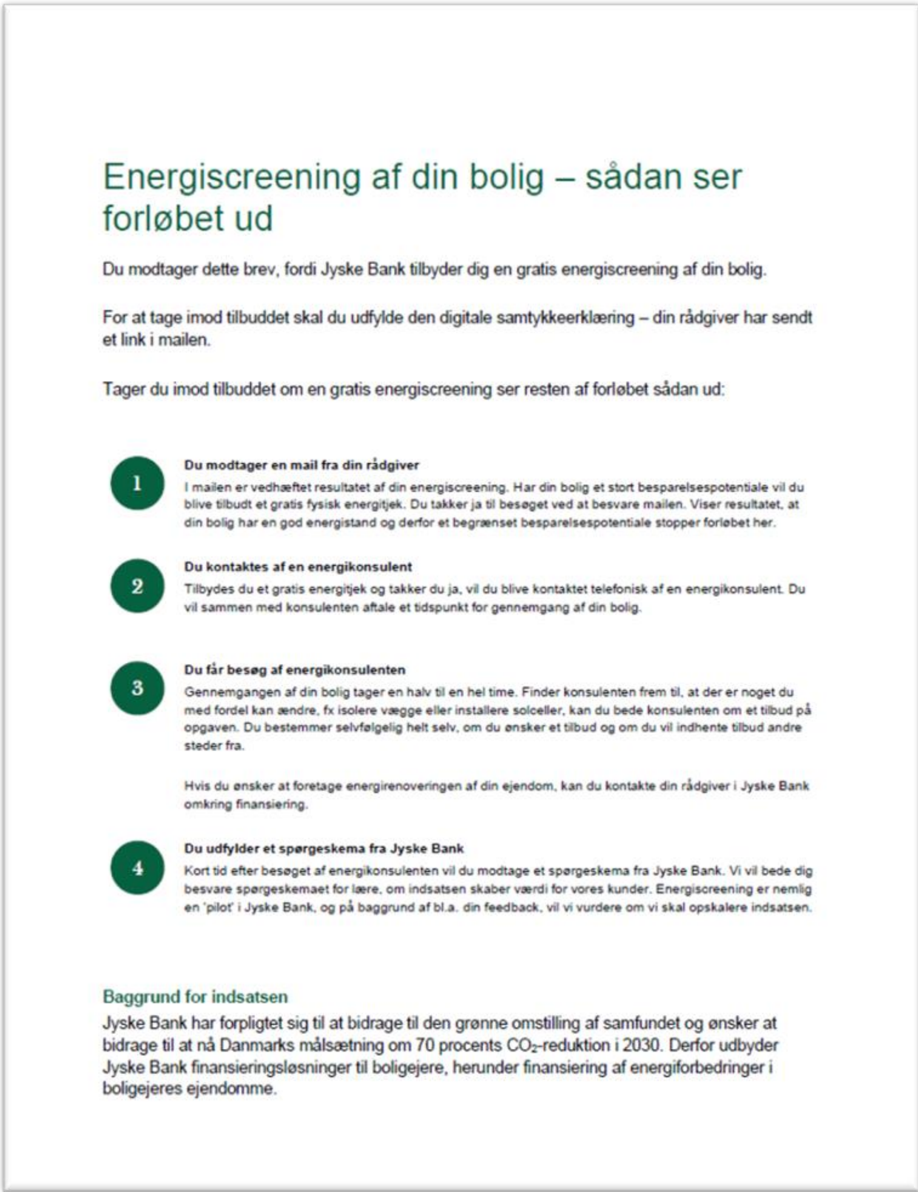



Source: Behavioural Advisory

In step 1, the NEEM Consortium hosted a kick-off workshop with Jyske Bank. In this workshop, the bank advisors were instructed on how to call out customers. The key question to ask was whether the client would like to participate in a free energy screening of their house. The last section of the workshop was scheduled for calling out. During a few hours, the five bank advisors contacted more than 40 customers, all of whom were pre-screened by Jyske Bank.

In step 2, if the client agreed to participate in the test, the advisor would send a message to the owners of the house. The owners were then to sign a consent form, giving permission to retrieve energy data for their house. The message included an explanation of the test in Figure 61.

Figure 61
Document sent to test participants explaining the steps of the NEEM initiative



## Energiscreening af din bolig – sådan ser forløbet ud

Du modtager dette brev, fordi Jyske Bank tilbyder dig en gratis energiscreening af din bolig.

For at tage imod tilbuddet skal du udfylde den digitale samtykkeerklæring – din rådgiver har sendt et link i mailen.

Tager du imod tilbuddet om en gratis energiscreening ser resten af forløbet sådan ud:

1. **Du modtager en mail fra din rådgiver**
   I mailen er vedhæftet resultatet af din energiscreening. Har din bolig et stort besparelsespotentiale vil du blive tilbudt et gratis fysisk energitjek. Du takker ja til besøget ved at besvare mailen. Viser resultatet, at din bolig har en god energistand og derfor et begrænset besparelsespotentiale stopper forløbet her.

2. **Du kontaktes af en energikonsulent**
   Tilbydes du et gratis energitjek og takker du ja, vil du blive kontaktet telefonisk af en energikonsulent. Du vil sammen med konsulenten aftale et tidspunkt for gennemgang af din bolig.

3. **Du får besøg af energikonsulenten**
   Gennemgangen af din bolig tager en halv til en hel time. Finder konsulenten frem til, at der er noget du med fordel kan ændre, fx isolere vægge eller installere solceller, kan du bede konsulenten om et tilbud på opgaven. Du bestemmer selvfølgelig helt selv, om du ønsker et tilbud og om du vil indhente tilbud andre steder fra.

   Hvis du ønsker at foretage energirenoveringen af din ejendom, kan du kontakte din rådgiver i Jyske Bank omkring finansiering.

4. **Du udfylder et spørgeskema fra Jyske Bank**
   Kort tid efter besøget af energikonsulenten vil du modtage et spørgeskema fra Jyske Bank. Vi vil bede dig besvare spørgeskemaet for lære, om indsatsen skaber værdi for vores kunder. Energiscreening er nemlig en 'pilot' i Jyske Bank, og på baggrund af bl.a. din feedback, vil vi vurdere om vi skal opskalere indsatsen.

### Baggrund for indsatsen

Jyske Bank har forpligtet sig til at bidrage til den grønne omstilling af samfundet og ønsker at bidrage til at nå Danmarks målsætning om 70 procents $CO_2$-reduktion i 2030. Derfor udbyder Jyske Bank finansieringsløsninger til boligejere, herunder finansiering af energiforbedringer i boligejeres ejendomme.

Source: Behavioural Advisory

In step 3, the advisor sends the energy screening result to the client. There were two versions of the one-pager: one for houses with large savings potential and one for houses with a small savings potential.

In step 4, the households with large savings potential could get a free house visit. This required them to answer the message from the financial advisor and then schedule a time for a visit by the energy partner.

In step 5, the bank advisors send a questionnaire to all of the clients participating in the test. The questionnaire is constructed by the NEEM consortium. Clients can voluntarily accept being interviewed in-depth on the phone by NEEM.

**Test results**
In the following, we present results from testing the NEEM Core Solution in collaboration with Jyske Bank. The results are divided into two sections: quantitative and qualitative results, respectively.

In sum, five main conclusions should be highlighted:

1. The NEEM Core Solution model finds that 45% of households (client sample) have a large savings potential.

2. Among households with large savings potential offered a free house inspection, 77% act and accept to be contacted. This reflects a large interest from clients to get feedback on energy performance.

3. Evaluation results show that 89% of households who only received the one-pager (small potential) think the overall experience from the Jyske Bank initiative was 'good' or 'very good'. This figure is reduced to 25% for households who were contacted by Bodil Energy.

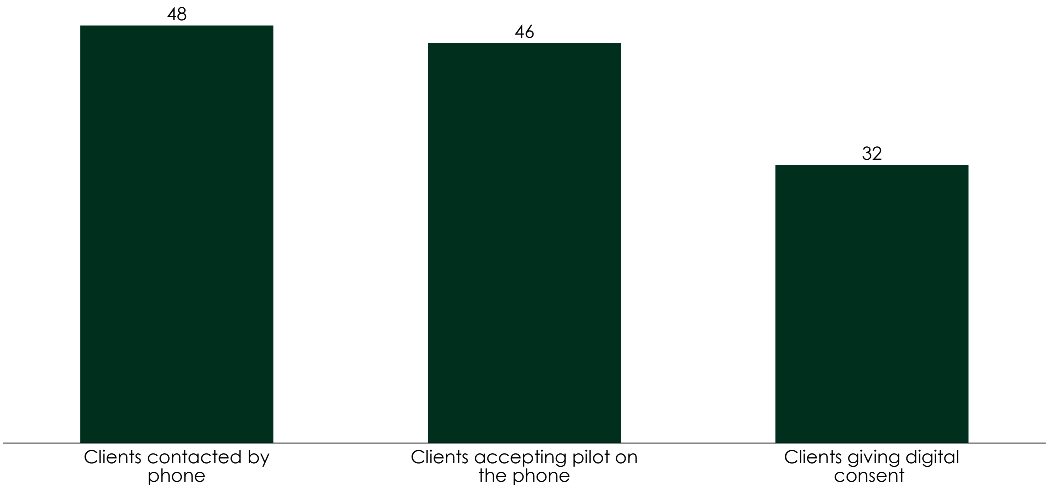
4. The main reason for negative feedback among clients talking to Bodil Energy is the inconsistency between the one-pager and the Bodil assessment.

5. Among households who only received the one-pager 78% think it is positive if Jyske Bank engages in energy initiatives. This figure is reduced to 50% for households who were contacted by Bodil Energy.

**Quantitative analysis of the customer journey**
The first result from the test with Jyske Bank is that 96% (46 out of 48 clients) accept having their house energy screened when phoned by a bank advisor, cf. Figure 62. This reveals a significant interest in discovering residential energy savings potential.

To have the house energy screened, all owners of the dwelling (often husband and spouse) must give their consent on the bank's digital platform. This requires some effort since they have to log in, find the right place and carry out the instructions. As can be seen in the figure, 70% (32 out of 46 clients) managed to do this.

Figure 62
Clients accepting test and later giving consent




Source: Behavioural Advisory

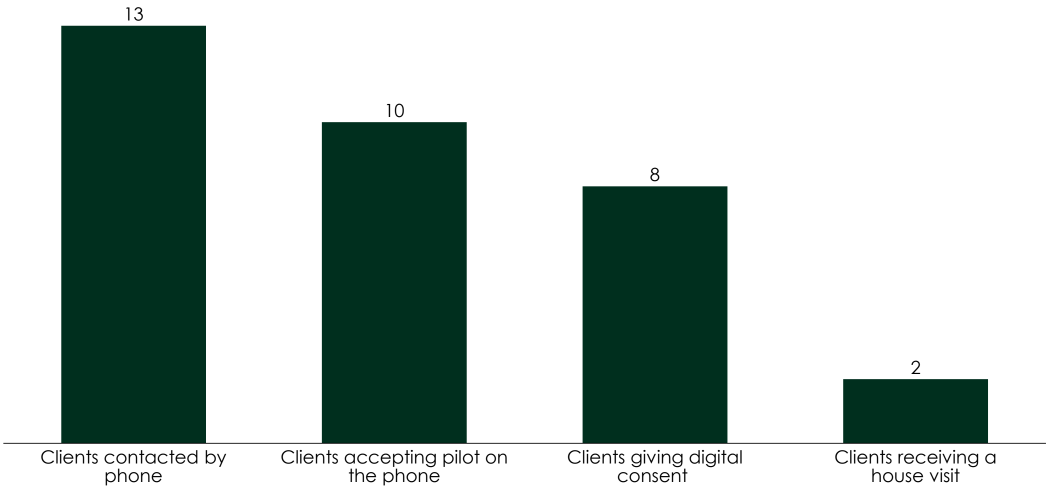
Among the 32 clients giving consent, 29 clients received a customised one-pager. For three clients TREFOR and Fredericia Fjernvarme could not provide data of sufficient quality to run the model.

The NEEM Core Solution model estimated 16 of the 29 clients to have a small savings potential (55%) and 13 of the 29 clients to have a large savings potential (45%). The 16 clients with small savings potential received their one-pager and were later asked to fill out a questionnaire for feedback.

The customer journey continued for the 13 clients with large savings potential. In total, 10 of the 13 clients accepted being contacted by an energy partner (77%), cf. Figure 63.

Of the ten clients, Bodil contacted and advised eight (80%). The result of the phone conversations was that only two of the eight clients needed an energy visit (25%).

Figure 63
Final steps of the customer journey for clients with large savings potential




Source: Behavioural Advisory

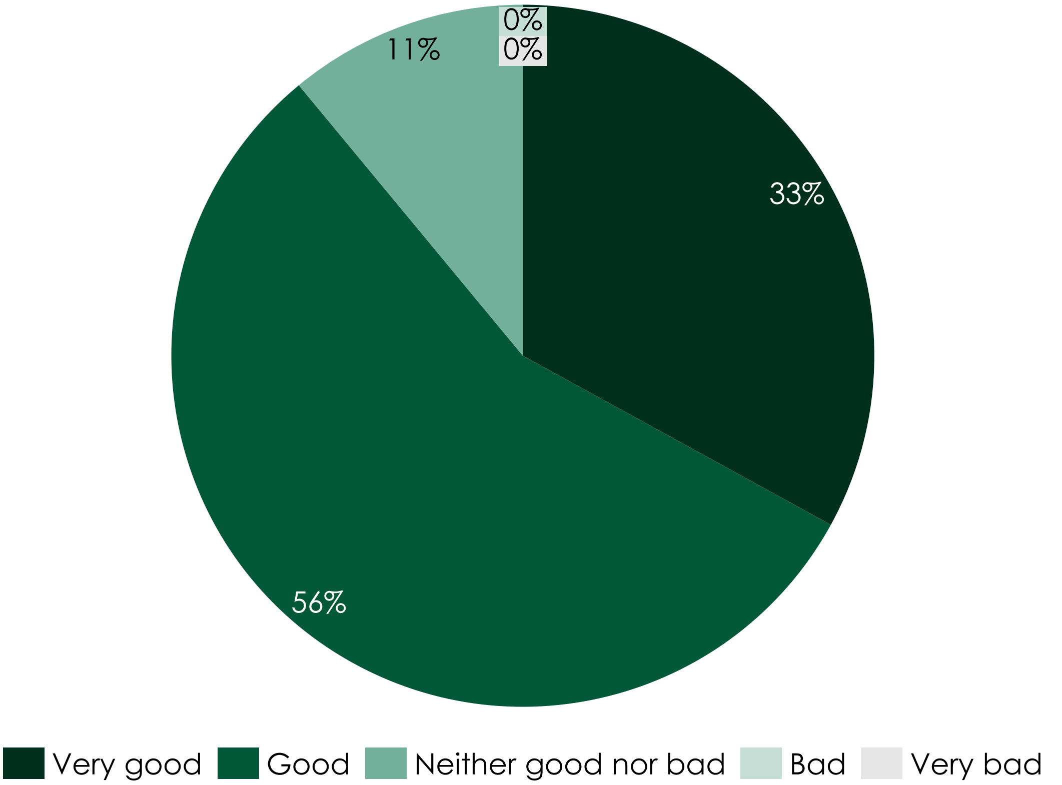
**Qualitative analysis of the customer journey**

In total, 13 of the 29 clients participating in the test filled out the evaluation questionnaire (45%). Of these, nine had small savings potential and four had large savings potential. Among the four with large savings potential, three ended their customer journey with a phone call with Bodil Energy and one received a visit. Two of the clients accepted a follow-up telephone interview – both clients with large savings potential.

**Feedback from clients with small energy savings potential**

The first conclusion from the survey is that eight out of nine (89%) think the initiative from Jyske Bank is ‘good’ or ‘very good’, cf. Figure 64. No one thinks it is ‘bad’ or ‘very bad’.

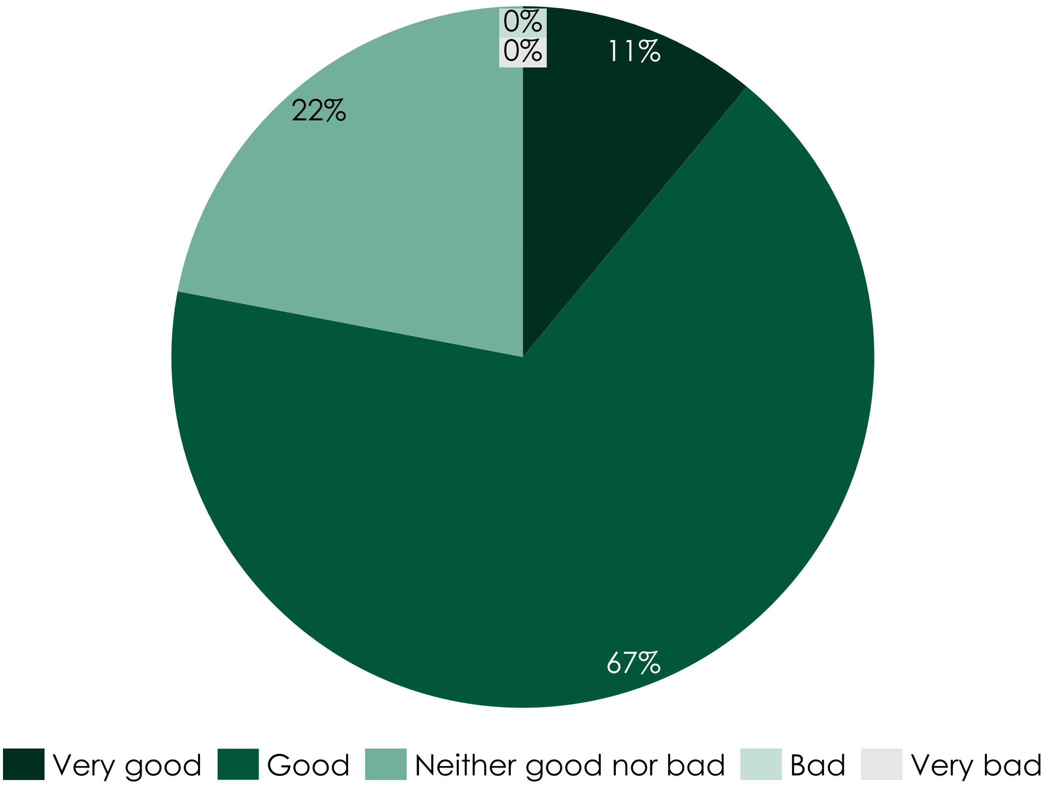
Figure 64
What is your overall experience of the offer from the FI for energy screening of your home?




Source: Behavioural Advisory

The second takeaway from the client feedback is that seven out of nine (78%) think the one-pager from Jyske Bank is 'good' or 'very good', cf. Figure 65. Again, no one thinks it is 'bad' or 'very bad'.

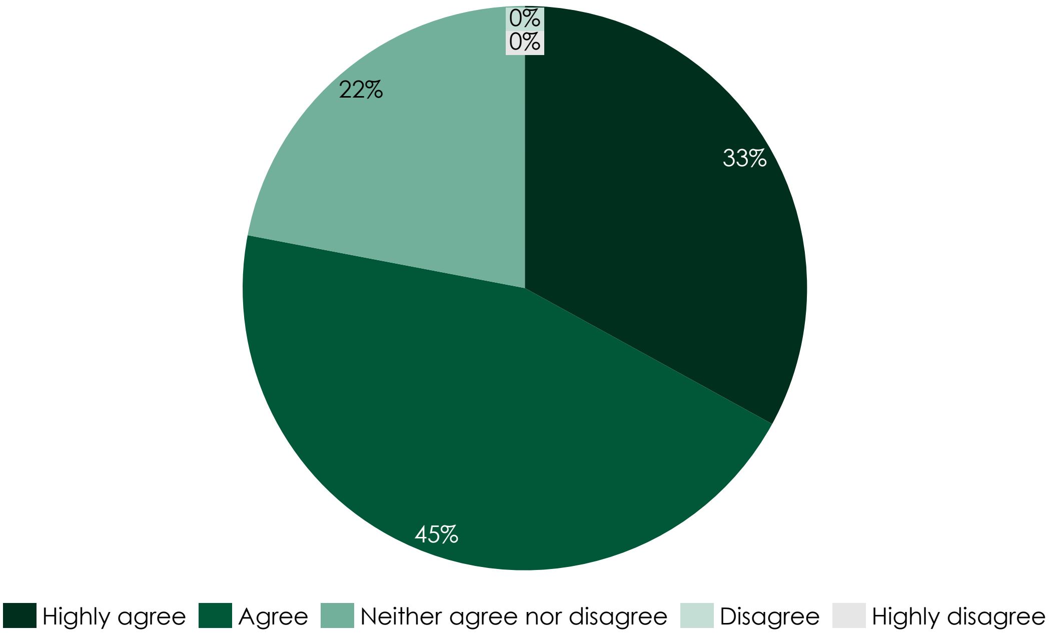
Figure 65
What is your experience of the digital energy screening, i.e., the PDF you were sent by the bank advisor?




Source: Behavioural Advisory

The third takeaway is that the one-pager for small savings is quite precise: No one believes the conclusion is wrong and seven out of nine agree (78%), cf. Figure 66.

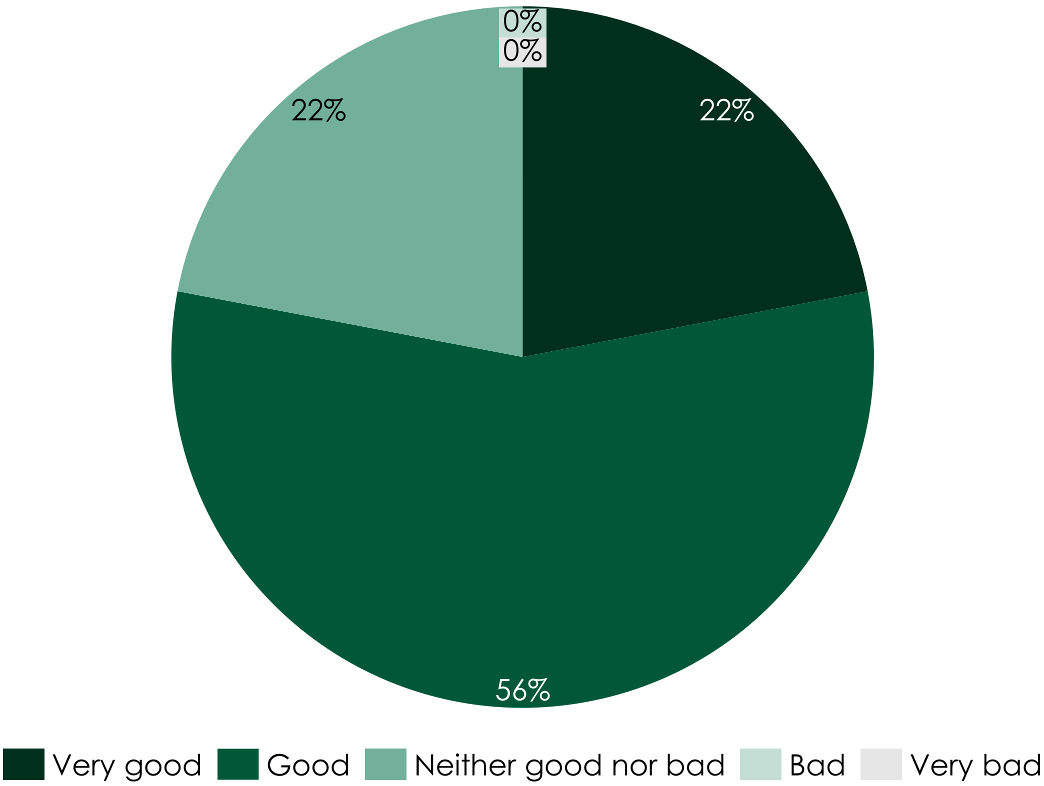
Figure 66
To what extent do you agree that it might not be profitable for you to renovate?




Note: The full question read "The result of the digital energy screening showed that your home has a high energy performance. The energy model estimates that the savings on heating bills will not be large enough to cover any energy renovation. To what extent do you agree that it might not be profitable for you to renovate?"
Source: Behavioural Advisory

Finally, the fourth conclusion is that clients receiving the one-pager for small savings potential think it is positive if Jyske Bank engages in energy initiatives. In total, seven of nine (78%) think it is positive if Jyske Bank does so more often in the future, cf. Figure 67.

Figure 67
What do you think about your bank doing this type of initiative related to the energy renovation of your home?

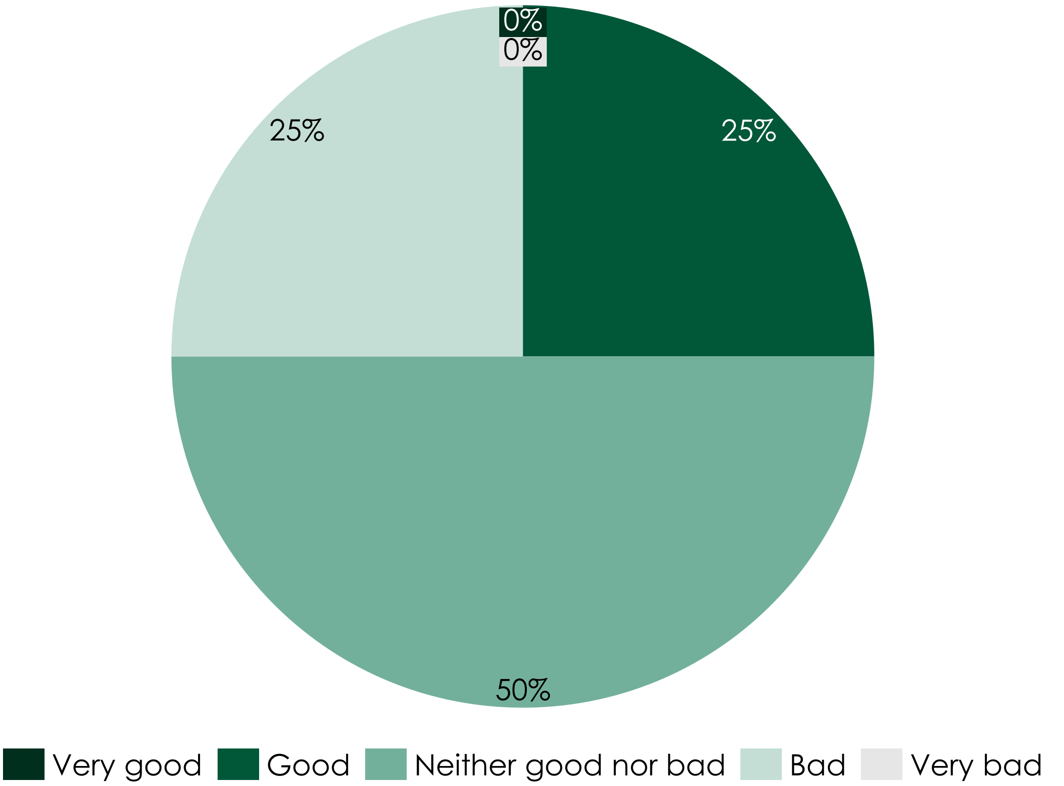



Source: Behavioural Advisory

**Feedback from clients with large energy savings potential**
The first conclusion from the survey targeting clients with large savings potential is that only 1 of 4 (25%) thinks the initiative from Jyske Bank is ‘good’ or ‘very good’, cf. Figure 68. This is in sharp contrast to the group with low savings potential.

Figure 68

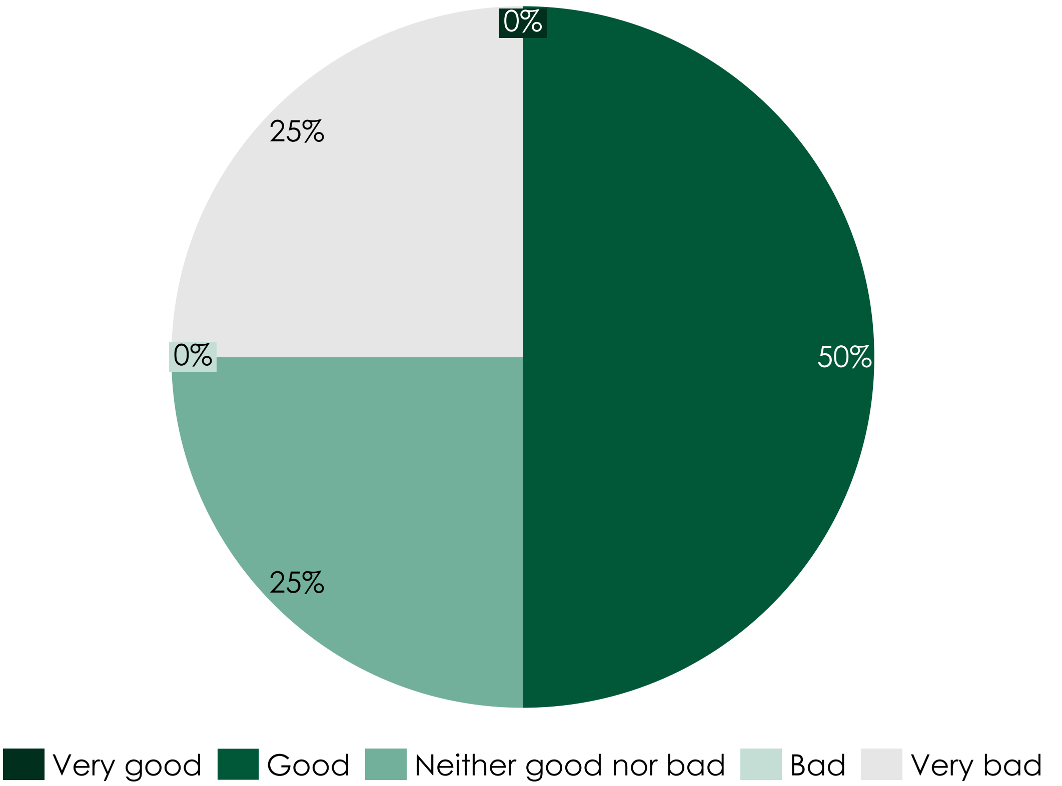
What is your overall experience of the offer from the FI for energy screening of your home?




Source: Behavioural Advisory

The second takeaway from the client feedback is that two out of four (50%) think the one-pager from Jyske Bank is ‘good’ or ‘very good’, cf. Figure 69. Again, this is lower than for the small potential group.

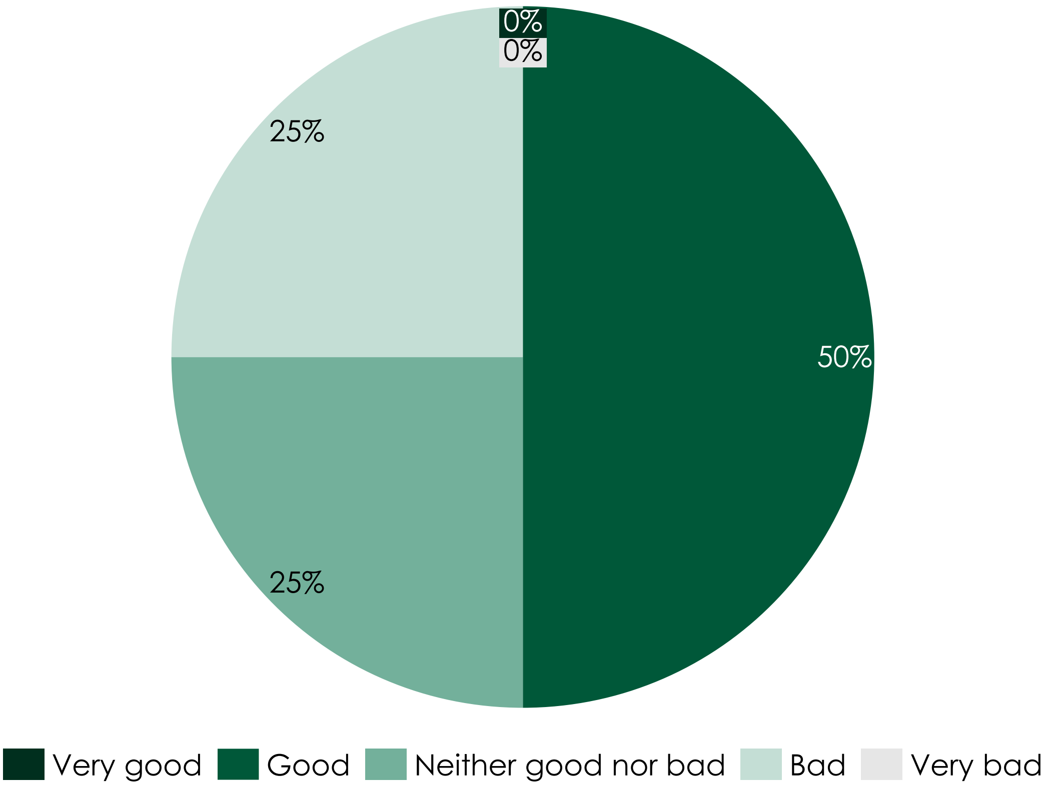
Figure 69
What is your experience of the digital energy screening - i.e., the PDF you were sent by the bank advisor?




Source: Behavioural Advisory

The third takeaway is that two out of four clients (50%) perceived the telephone conversation with the energy partner Bodil Energy as 'good', cf. Figure 70.

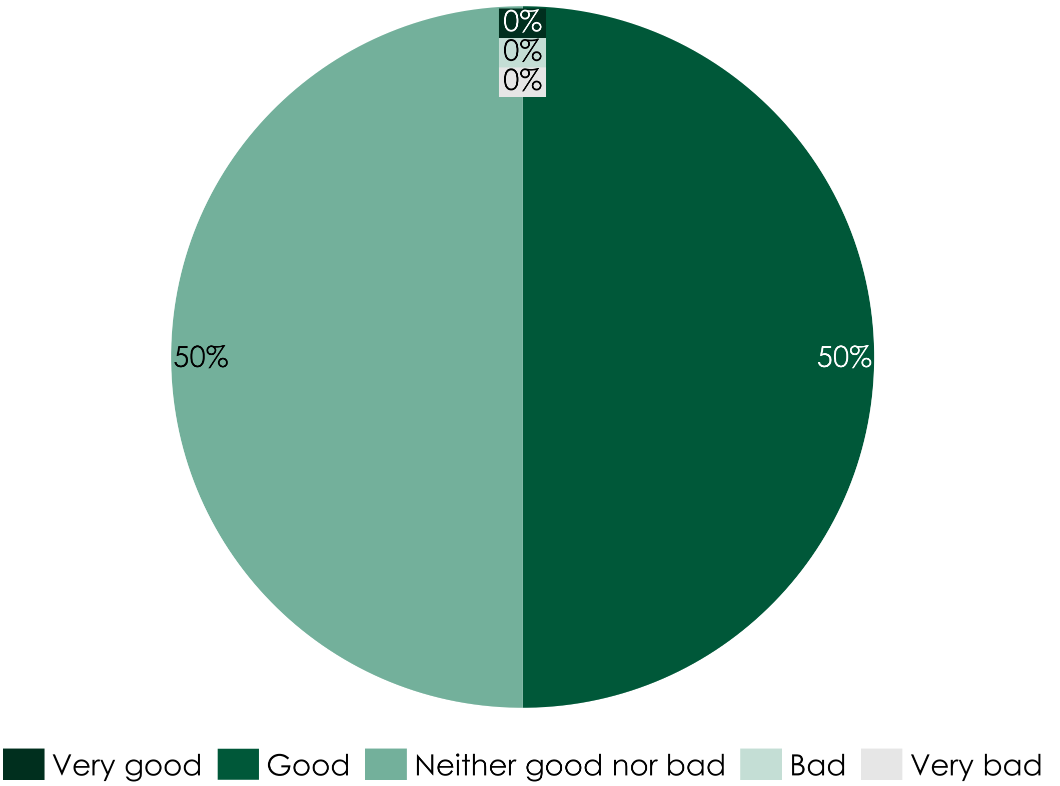
Figure 70
What is your overall experience of the telephone conversation you had with the energy advisor from Bodil Energy?




Source: Behavioural Advisory

Finally, only half of the respondents among clients with large savings potential think it is 'good' or 'very good' if Jyske Bank launches green initiatives, cf. Figure 71. The corresponding figure was 78% for the group with low savings potential.

Figure 71
What do you think about your bank doing this type of initiative related to the energy renovation of your home?




Source: Behavioural Advisory

**Evaluation by Jyske Bank**
Jyske Bank has a very positive perception of the NEEM Core Solution. They believe that the concept of the NEEM Core Solution is very good. They perceive the NEEM Core Solution as a good idea to activate homeowners to think about energy renovating their homes. However, they regret that the test was not a type where evidence could be provided about whether the model for predicting the potential for energy renovations predicted correctly.

The behavioural part of the project was also evaluated very positively. Quoting Jyske Bank: "Almost 100% of the homeowners asked to participate in the test accepted to participate. So, from our side, the behavioural work done was very good."

The key takeaway for having participated in the NEEM Hub for Jyske Bank was that homeowners are eager to be informed about potential energy renovations in their homes. Further, homeowners can be activated, but it is more difficult to predict if there is a profitable potential for energy renovation.

For the headquarters, a challenge was to assess the financial costs versus the benefits of pursuing the green agenda in the NEEM project and similar approaches. There was a doubt whether the time spent by employees (costs) to test the NEEM Core Solution would lead to sufficiently increased sales and closer relationships with the homeowners.

Another challenge was a concern about how the homeowners would react to the bank contacting them regarding energy renovations. Most advisors saw the potential in getting closer to the homeowners with the NEEM Core Solution. The main barrier was the advisors' concern about becoming energy advisors to the homeowners instead of economic and financial advisors.

Asked about Jyske Banks' vision related to the green agenda, the answer is extremely positive from a NEEM Hub point of view. Quoting Jyske Bank:

"We want to be relevant for our customers when it comes to energy renovations – data-driven tools like NEEM Core Solutions can help us with this in an efficient way. (…) It is time-consuming and often difficult for private homeowners to know if it is worth the cost to renovate their home. The NEEM Core Solution helps them to get an idea if there are potential cost savings from renovating. (…) With the good response we got from the homeowners in the test, we expect to do more like this going forward."

## TEST RESULTS – ELVIA AND SWEDBANK

In collaboration with the Norwegian utility company Elvia and the Swedish bank Swedbank, we have tested the NEEM Core Solution in Norway and Sweden, respectively. As the two tests are similar, we present the customer journey and the results together in the sections below.

In both the Elvia and Swedbank tests, the one-pagers did not offer a house inspection in case of large savings potential. The reason is that we did not team up with an energy consultant as the case was in the previous tests. This significantly reduced the value proposition of the test and also changes the purpose of the participant evaluation.

Instead of perceiving participants as customers whom we want to act, we invite them into the 'machine room' and ask for technical feedback and overall thoughts. This makes sense as the participants were internally recruited by Elvia and Swedbank and were well-informed of the purpose of the test.

**The customer journey of Elvia and Swedbank tests**

Below we have illustrated the customer journey for Jyske Bank, Denmark, in which clients are contacted by phone and clients with large savings potential are offered a free energy visit by a commercial partner. The complete journey consists of three steps explained in the following.

Figure 72
Customer journey of the NEEM Core Solution

**1 Swedbank/Elvia recruit participants for the pilot**

- Swedbank/Elvia make use of internal network to create a panel of participants for the pilot
- The participants sign consent form allowing NEEM to retrieve energy data on their behalf

**2 Participants receive one-pager with energy results**

- Participants receive customised one-pager with savings potential based on the NEEM core solution
- In these pilots there are no CTA. The one-pager presents only the results of the energy screening.

**3 NEEM collects feedback**

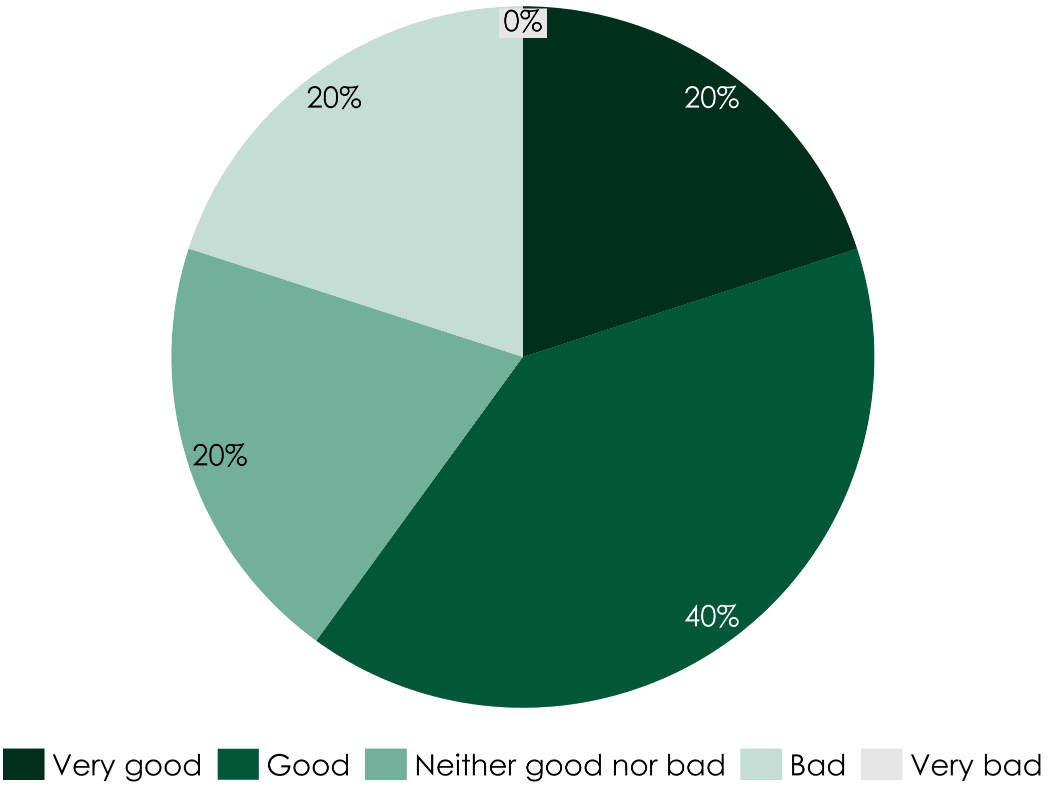
- NEEM sends questionnaire to the participants asking for feedback on initiative
- Participants who ticks off a box are interviewed in depth (20 min)

Source: Behavioural Advisory

In step 1, Swedbank/Elvia used their internal network to recruit participants for the test. In step 2, the participants received tailored one-pagers based on the NEEM Core Solution. In Norway and Sweden, we teamed up with an energy consultant so there was no CTA in the one-pagers. In that sense, the value proposition in the one-pagers was significantly reduced compared to the previous tests. In step 3, we evaluated the test by sending out digital questionnaires and inviting in-depth follow-up interviews.

**Feedback from participants in the Elvia test**
The overall impression of the digital screening is positive. In total, 60% of the participants perceive it as 'very good' or 'good'.

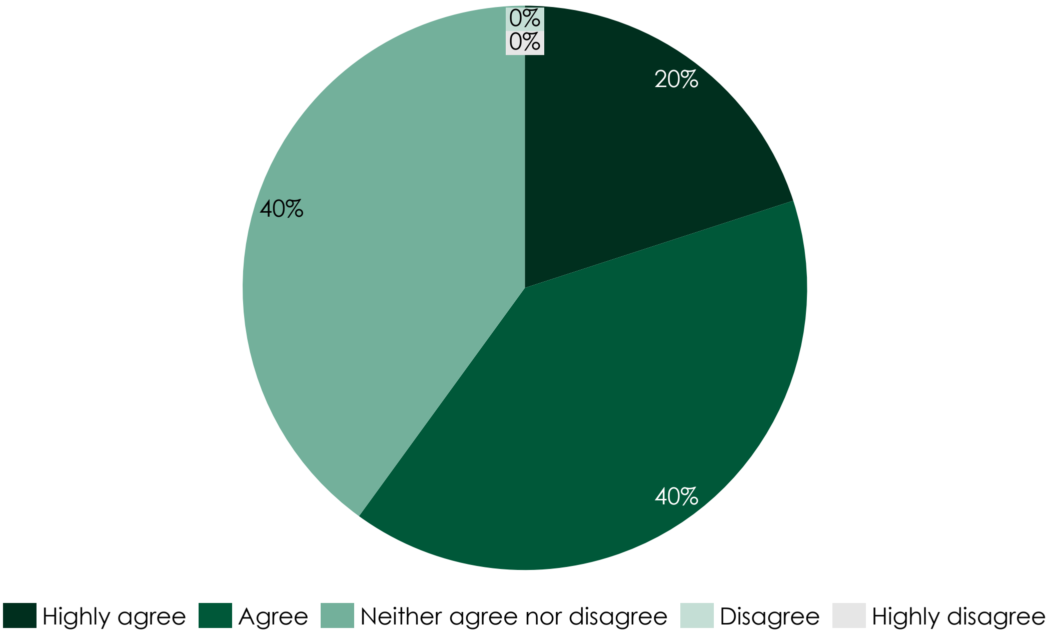
Figure 73
What is your overall impression of the digital energy screening of your house (the PDF you have received)?




Source: Behavioural Advisory

Most participants agree with the conclusion of the NEEM Core Solution on whether the house has a large or low energy savings potential. In total, 60% of the participants answer, 'highly agree' or 'agree'. No one disagrees.

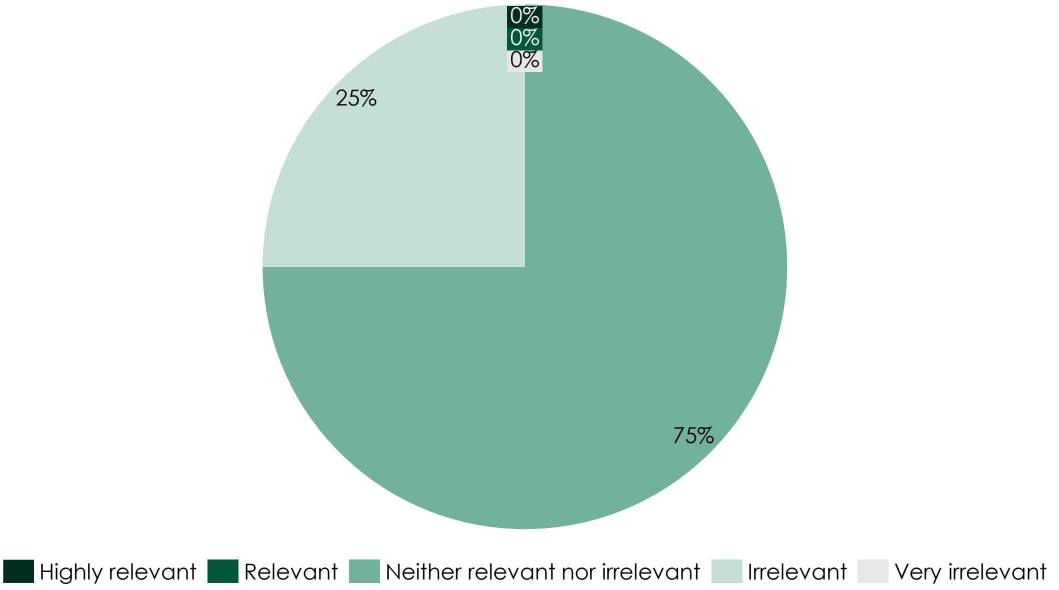
Figure 74
To what extent do you agree that it might not be profitable for you to renovate?




Note: Full question was "The result of the digital energy screening showed that your home has a high savings potential. To what extent do you agree that it might be profitable for you to renovate? OR The result of the digital energy screening showed that your home has a high energy performance. This means that the energy model estimates that the savings on heating bills will not be large enough to cover any energy renovation. To what extent do you agree that it might not be profitable for you to renovate?"
Source: Behavioural Advisory

The technical content of the energy screening is not found very relevant. In total, 75% find it 'neither relevant nor irrelevant' and no one finds it 'relevant' or 'highly relevant'. This might be the case since the technical information was reduced compared to the other tests due to estimation issues.

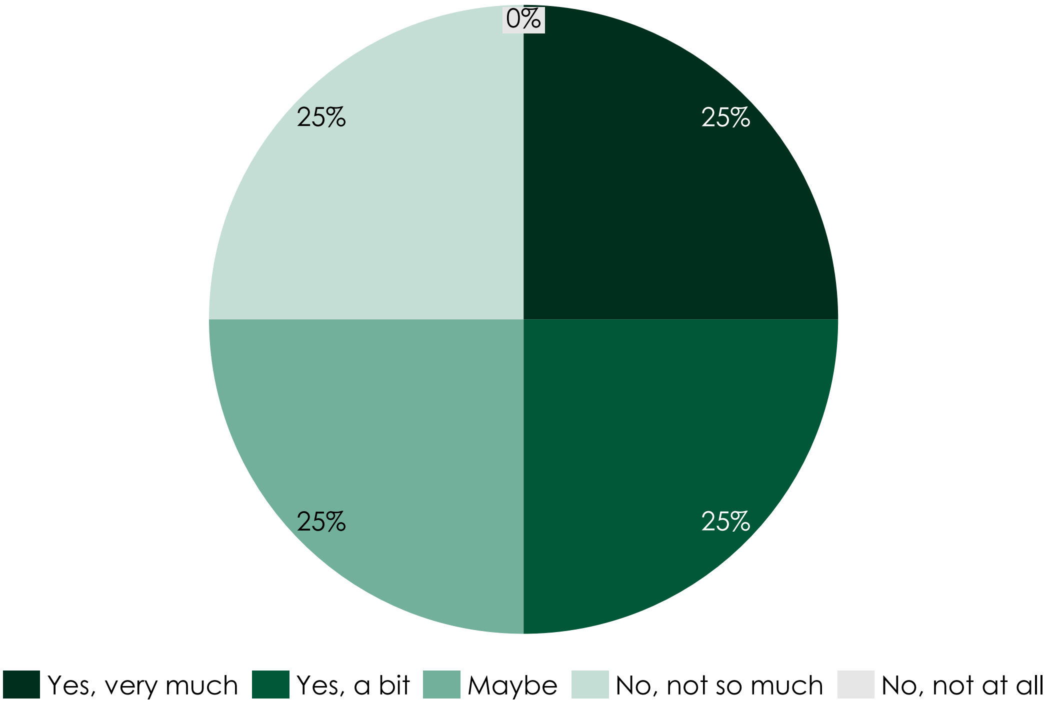
Figure 75
How relevant do you find the technical content of the energy screening?




Source: Behavioural Advisory

In total, 50% of the participants think that the average Norwegian household will find it interesting to have their house energy screened. The relatively low share might reflect the limitations of the model, and hence the one-pager, in the test.

Figure 76
Do you think it would be interesting for an average Norwegian household to have their house energy screened in this way?




Source: Behavioural Advisory

Open-ended responses in the questionnaire and follow-up interviews on the phone partly reveal the reasonings behind the above answers. The overall takeaway is that the one-pager has too little information and the receivers are not much wiser after having read it. As there is no call to action, the value of the energy screening is perceived as extremely limited.

## C.3 RESULTS FROM HEMMA AND BODIL TESTS

In this chapter, we first present the test results from the Hemma test. We then present the results from the test run by Nordea in collaboration with Bodil.

### TEST RESULTS – HEMMA

The Hemma solution is developed by Hemma and tested in collaboration with Nordea Sweden. In the following we first present the purpose and workings of the Hemma solution, then the adaptation to test the solution in the NEEM Hub, then the results and improvement areas and finally Hemma's learnings and takeaways from the NEEM test.

**Purpose and workings of the Hemma solution**

The platform helps banks understand the potential of their building stock, set relevant targets for reducing emissions, and translate these targets into concrete actions so that they know what needs to be done.

In terms of purpose, with the plug-and-play user interfaces, banks can proactively support households on their journey to net zero by identifying the most relevant and necessary renovation activities, promoting financial products to help households afford the investment, connecting them with relevant installers available on the Hemma platform, following up the process and evaluating the impact.

In terms of workings, EP and consumption data are stored and continuously updated back-end, enabling banks to have an always updated view of the current state of their building stock. The workings of the Hemma platform are described in detail in Box 3.

**Adaptations of the Hemma solution for the NEEM test**
Several adjustments to the Hemma solution were made according to Nordea requirements in the NEEM test. Areas of the Hemma solution that were evaluated and scrutinised before the market test were, e.g., the overall user experience, Hemma's algorithms, legal texts and communication throughout the customer journey, third-party (installers) Service Level Agreements, presentation of Nordea's financial products and more.

The NEEM test and the Hemma solution were adjusted based on insights and observations of test users and their collective feedback. This involved, for example, improving the login experience, clarifying the questionnaire, improving the way recommended activities were presented, increasing transparency of assumptions and calculations, presenting and selecting installers in the service, presenting financial products in the service, including the advanced calculator enabling end users to create different scenarios (e.g., what if interest rate increases, or how that affects payback time), and colours and placement of CTA buttons throughout the service.

The purpose of conducting the market test was to demonstrate and ensure that the Hemma solution works in a real-world case and with desired results. In other words, the purpose was to investigate whether the Hemma solution is appreciated by the end users and the Nordea staff and activates households to invest in concrete energy efficiency projects.

Box 3 The workings of the Hemma platform

- The Hemma platform is a full-stack platform with both client and server-side components. It is hosted by Hemma on Amazon Web Services for all clients running the platform.
- The platform has server-side integrations to collect data from external data sources such as national records for building data, EP data, and geo data.
- Via standardised user interfaces running on top of the platform, it enables collecting first-party data from end users (e.g., heating system, household information or undergone renovation activities). It also collects power of attorney to access and monitor electricity meter data directly from the household, and user consent to share the collected data with third parties, e.g., a bank.
- The aggregated data (e.g., building data, EP data and consumption data) are stored in a persistent state and continuously updated through server-side integrations.
- The platform includes proprietary algorithms and models for calculating the EP of single-family homes and how it can be improved through various energy renovation activities. Algorithms and models are trained and continuously improved over time by validation vs actual impact after carried out projects.
- The platform capabilities are made available to customers such as banks and energy companies through Hemma's white-label front-end solutions or by consuming Hemma's API directly, using the bank's front-end.

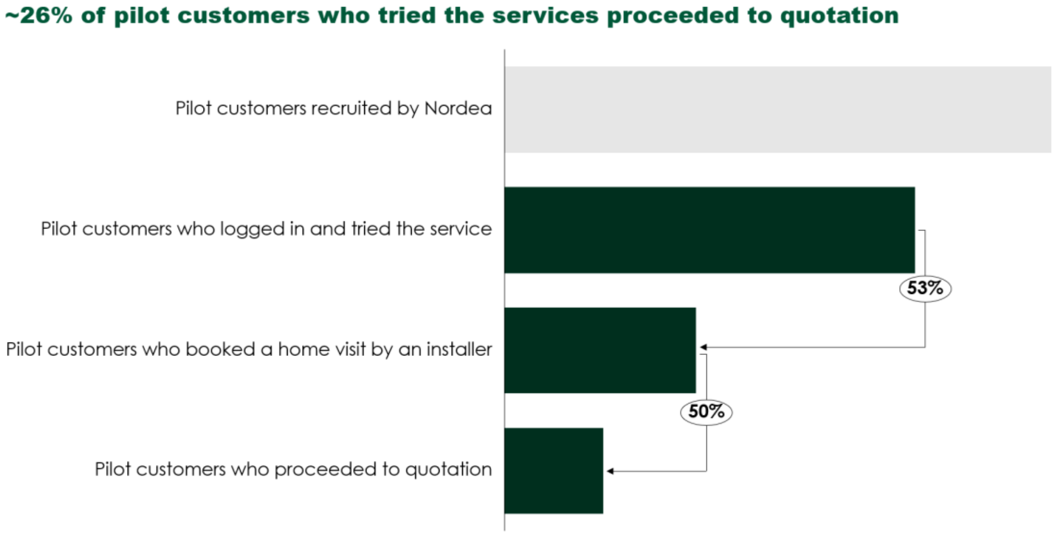
**Design and results of the NEEM test**
The test was conducted in collaboration with Nordea Sweden following six steps:

1. Training packages for mortgage advisors and customer service were created and executed by Hemma together with Nordea at multiple locations in Sweden.
2. Marketing material was created in cooperation with Nordea describing the test and the Hemma solution, messaging, the story behind Nordea's objective and the overall purpose.
3. A sample of target households was selected by Nordea with input from Hemma, based on several parameters, e.g., geography (Stockholm, Göteborg, Malmö), type of building, and building year.
4. Both external and internal user testing was made before the launch. External test users tried out the Nordea test service to test hypotheses and gain insights about how end users experience Hemma's solution. Internal test users, mainly mortgage advisors and customer service at Nordea, tested the Nordea test service to give their point of view based on their experience with other digital services that Nordea provides.
5. The Nordea test service and the Hemma solution were adjusted based on insights and observations of test users and their collective feedback.
6. Nordea then marketed the test service towards the sample target group until 50 households had gone through the service end-to-end, i.e., tested the digital tool, selected an energy renovation activity, selected financing from Nordea, and booked an installer for an onsite visit.

In terms of results, the Hemma test was well received both among Nordea customers and Nordea staff, from both conversion and customer satisfaction perspectives. Several concrete improvement areas and aspects to take into consideration for further development were also collected.

In terms of conversion, >25% of all households testing the service selected an energy renovation activity and booked an onsite visit with at least one installer. This is a considerably high conversion for an online service, especially considering the size of investment for these types of activities. Most households in the test went for solar panel installations.

Figure 77
The conversion rate in the Hemma test




Source: Hemma and Nordea

In terms of customer satisfaction, 46% of participants had a positive (Score 4-5) overall impression of the service whereas only 14% had a negative (Score 1-2) overall impression. Customers appreciated the low effort, cost indications and access to suppliers that the overall service concept offered. In total, 61% of participants had a positive (Score 4-5) overall impression of the Hemma flow whereas only 18% had a negative (Score 1-2) overall impression. The flow is seen as a smooth and effortless way to get suggestions and acts as a push for action.

The two main areas for improvement include the experience flow in the platform and aspects of the external partner, i.e., the suppliers of energy solutions.

Customer feedback on possible improvements to the flow of the digital platform:

- Making the potential cost savings and payback time more visible as several had not noticed this despite it being important to them
- Clarifying what data are general (based on a geographical area and type/age of house) and what is property specific (and being able to add actual consumption and energy price to make it even more precise and give more value as opposed to being just sales)
- Improving the navigation flow as a few felt it was cumbersome on mobile devices
- Possibility of selecting more than one primary source of heating and adding more options (such as wood burners) as available sources

- Possibility of "forcing" a specific energy initiative that the customer already had in mind from previous research or knowledge to see the estimated cost, savings, payback time and suppliers
- Expanding the flow or service to include, for example, home automation or replacing lighting to save energy consumption and other similar potential home improvements

Areas involving the suppliers that may be improved:

- Suppliers are often too quick to contact. Many participants felt suppliers were too quick to contact them after the flow, leaving too little time to discuss and reflect before moving ahead.
- Bigger choice and quality of suppliers. Some would like to have a wider choice of suppliers and the possibility of choosing a supplier depending on preference (for example, locally situated, long market experience or best price). There were also some comments on especially the solar panel suppliers not being the best.
- Clear information and expectations on setup are required. It was also mentioned that some suppliers were under the impression that the customers had already sorted their financing and were ready to decide on going ahead with the initiative. All suppliers should be clear about the setup to avoid misunderstandings.
- Adding customer recommendations to create trust. A suggestion was made to add customer reviews and recommendations for the suppliers involved, as it is often difficult to feel confident about the supplier's quality. This could motivate more customers to go ahead.

**Hemma's learnings and takeaways from the NEEM test**

The market test shows the concept of the Hemma solution works. The banks and households need and expect this type of service. Banks are expected to play a role and have the authority to speak to households in these matters from the position of advisors in household economy and property-related matters. This is further amplified by aspects such as soaring energy prices, general awareness, willingness to invest in energy efficiency among households, and the increasingly evident impact EP has on property value.

In general, providing new solutions to customers operating in a heavily regulated environment is complex and takes time as many legal, compliance and risk-related matters are often assessed and evaluated. Also, in this area, many different stakeholders are involved, e.g., brand and marketing, lending, legal, sustainability, risk, and digital services departments.

Hemma sees that the new and evolving regulations call for greater transparency and disclosure of ESG-related data. Several Swedish banks have communicated concrete targets for reducing financed emissions of their mortgage portfolio by 2030. Hemma also sees a demand and an expectation for this type of service from households as the awareness and willingness to invest in energy efficiency increases.

However, Hemma finds many banks in an early phase in terms of understanding how to measure, pursue and achieve targets from both customer and operational perspectives. A large part of adapting the Hemma solution to the banks is about understanding and helping banks establish ways of working to systematically understand and improve the EP of their building stock and make it an integral part of their business processes and overall customer journeys to help their customers with the green transition of their properties.

## TEST RESULTS – BODIL ENERGY

In a test in collaboration with Nordea Denmark, the NEEM Consortium collaborated with Bodil Energy and evaluated concrete outreach strategies to promote investments in solar panels. The results were encouraging for both Nordea and Bodil and the approach and solutions on both sides were scrutinised based on the input of NEEM.

The test was conducted in collaboration with two Nordea branches located in Roskilde and Ringsted. Bank advisors were instructed to promote solar panels by recommending that customers make contact with Bodil or have Bodil contact them. Bank advisors were instructed based on presentations from Nordea and Bodil to which NEEM had given input.

An analogue approach based on training employees in promoting solar panels at customer meetings is an extremely difficult goal to achieve. This requires the advisor to step out of their comfort zone and propose green solutions face to face. The results show that only 10% of the bank advisors proposed solar panels in practice, which is a relatively low share. However, those who did were extremely successful, and client feedback from interviews shows that the bank is rated positively for its initiative in the green agenda.

Nordea recruited customers who had invested in solar panels for the evaluation conducted by NEEM. The evaluation was conducted through phone interviews. In addition to interviewing the clients, NEEM analysed best-practice bank actions by interviewing the best-performing bank advisors. The evaluation results of the test are presented below.

**Clients are satisfied with Bodil and the recommendation by Nordea**

On a scale from 1 to 5, with 1 being 'very unhappy' and 5 being 'very happy', Bodil scored 3.1 for overall performance. This reflects that customers are on average satisfied with the Bodil solution and the recommendation by Nordea. Scores and selected quotes from the clients appear below.

Score 5. "That's a five! They just finished. It just went so well."

Score 5. "Super good. The consultants came out. Then they just took over from there."

Score 4. "I was calm a long way down the road."

Score 4. "Almost fully satisfied."

Score 3. "There was an extra bill that I think Bodil is responsible for."

Score 2. "Complications arose, but Bodil didn't help much there."

Score 1. "I would not recommend Bodil as an advisor."

Score 1. "Emil has clocked it. I am dissatisfied."

The main positive features highlighted by the clients are a good process, a fair price and reliable advice. Below are some of the quotes documenting the benefits of choosing Bodil as a partner.

"The installation went well. All was good in the process."

"It all just played out. Offers from Bodil, Verasol, solar cells and heat pumps. Everything is good."

"I have written to several suppliers. First and foremost, it is the price. The solution by Bodil was reasonably cheap. The others who I considered had a price above DKK 100,000. Mikkel said that we do not need a large heat pump."

"It didn't make sense to get a heat pump when district heating is planned. (…) Yes, I would clearly say that good advice creates credibility."

"[About what is best] The credibility of Bodil. Mikkel gave good advice. He went out and inspected the house. He had charts and typed things in so he could see what needed to be done."

When Bodil receive critique, it is often due to very high expectations. A takeaway is therefore to manage expectations better. Although the solution delivers very high client care compared to other suppliers, it is not possible to predict all types of likely challenges when looking at the roof 30 minutes from the ground at first inspection. But expectations are sometimes that this should be the case.

The formal partnership between Nordea and Bodil is perceived very positively by the clients. The partnership creates trust in Bodil and increases the belief that the client will get a loan to finance the solution. Below are some of the quotes supporting this finding.

"My husband saw on the internet that you could get solar panels via Nordea. It was the smartest solution because Bodil had an agreement with the bank. It was the smartest and easiest thing."

“It was our bank advisor at Nordea. She said there was a collaboration with Bodil. It was perfectly fine with the recommendation. When it's through Nordea, it can't be all bad. We thought we would play it safe. In terms of price, it was roughly the same.”

“I had a conversation with my advisor. She suggested Bodil Energi. The price was in the high end, but I could see the idea in it.”

“We watched a webinar. We thought it was a good idea that it was via the bank. Then there was a greater probability of getting the loan.”

“I saw the collaboration on Nordea's website. I then contacted Bodil directly.”

Very importantly, Nordea receives big kudos for promoting green solutions; everyone thinks the initiative is good and wants more. Below is some of the relevant feedback from clients.

“[Asked if Nordea should take similar measures] Yes, by all means. That's solely a good thing.”

“That's a great idea.”

“It is a good initiative. I don't think there is anything that could have been done better”.

“Yes, I would recommend it. It is a good idea. Especially in these times.”

“I think it's perfectly fine. Many people have solar panels today. It is an investment. It makes good sense for the bank to offer it. I think it is good that they offer the option of making an agreement through the bank.”

“So, the financial sector is just about making money. Nordea wants to sell. Missions about one thing and the other about greenness, I do not believe in that. But the offer is good and it makes sense to propose giving loans. So it's fine, even if it's about money.”

**Takeaway from interviewing best-performing bank advisors**
The approach of the best-performing bank advisors is based on sincere questions, humility and effective objection handling.

If the customer owns a single-family house or an electric car, the advisor starts asking a series of questions, first open and then more direct; see examples below.

- What do you think about all the turmoil happening in the world? Is it something that affects your finances, for example, the rising energy prices?
- How long have you lived in the house? What are your plans? How long do you plan to stay?

- Do you have thoughts about changing anything? Does it need to be re-built a bit?
- What do you think about solar panels? Is it allowed in your neighbour-hood?
- May I send one of my colleagues out to you?

The best advisors handle objections very well, and the conversation stays pleasant no matter what is objected to. Objections such as "It's expensive" or "What does that have to do with you?" are handled by showing understanding and pointing out facts that apply to most other customers similar to the one in the conversation.

Concrete examples of good objection handling:

- "I can easily understand what you are saying. I don't know how regulations are at my place either. But my colleagues know all about that, so…"
- "I can easily understand what you are saying. All I know is that many others have saved DKK X and were really happy with the offer."
- "I can easily understand what you are saying. All I know is that if you say yes, Bodil will come and do everything from A to Z. And I'll be right here if there's the slightest thing."

Most of the best-performing advisors are fiery souls. They are great for the bank but difficult to copy. They find the green initiative 'very exciting'. They are motivated by the fact that Nordea is leading the way, seizing things that are moving in society and offering great value propositions to customers.

In one case, Bodil sent an email thanking an advisor for referring ten customers to them, which made her feel "like the most special advisor in Nordea Denmark". The reason advisors like her are significantly better at bringing Bodil into play is personality traits and qualifications, which are difficult to copy. However, Nordea can take some measures to spur more activity among advisors. More and closer follow-up, particularly from the head office, is a factor that can get colleagues to become more active.

**Other NEEM initiatives in collaboration with Nordea Denmark and Bodil**
In addition to the NEEM test promoting solar panels, the NEEM Hub has contributed to two other tests run by Nordea in collaboration with Bodil. Particularly in the behavioural domain, NEEM has conducted workshops and given feedback on digital letters, websites, touchpoint-hotspot outreach channels, and questionnaires, collecting feedback through telephone interviews and evaluating initiatives.

In the first test, the digital test promoting heat pumps, Nordea Denmark wrote a combination of direct messages with a link to the website and direct messages with invitations to a webinar. The approach yielded impressive conversions: Among 100 positive reactions to digital letters, 96.9% received a report, 40.1% had their house inspected and 13.4% carried out a refurbishment. The numbers were counted three months after initiating, which means that some may still act, as refurbishments usually take time from thought to action.

In the second test, the analogue test promoting heat pumps, Nordea Denmark called customers and asked if they would be interested in being contacted by Bodil Energy. Highly interesting, this approach was only slightly more efficient compared to the digital in terms of conversion: Among 100 calls with positive feedback, 93.6% received a report, 30.1% accepted a site visit and 13.7% decided to renovate. These impressive figures prove how receptive clients are and how much value the FI can create through a well-functioning partnership.

As a tool for handling the potential concerns of the clients, the advisors were handed and trained in the 'concern-answer' document presented below.

Table 22
Concern-Answer document for Bodil advisors

| POTENTIAL CONCERNS AS A CLIENT | GOOD ANSWERS AS AN ADVISOR |
|---|---|
| It is expensive in terms of establishment costs if you compare it with a gas or wood pellet stove. | The climate-friendly heat pump today indeed costs more in terms of mere installation. The current costs for fuel vs. heating electricity make the heat pump profitable over time in many cases. |
| A heat pump makes noise outside. | A heat pump is not silent, but many of the prejudices about noise nuisance from heat pumps originate from old or cheap models. Bodil only sells modern pumps, with an outdoor noise level of approximately 59 dB, which is difficult to hear from 3m away. |
| It doesn't look pretty. | The appearance of the heat pump varies by model and price range. Bodil's installers have a dialogue with the customers about where the pump is best placed. |
| It is not interesting for us because we would rather wait for district heating. | Heat pumps are on average cheaper than district heating, and on average more climate-friendly. However, since there is great variation in district heating systems and prices, it is best not to generalise. Bodil is happy to help the customer investigate what is the best solution for them. |
| It is not interesting for us, as we have/want to switch to district heating. | If the customer is required to connect, the customer must use district heating. If the customer is not obliged to connect, the profitability depends on the local district heating price. In some cases, there may be a good case for switching from district heating to a heat pump. |

Source: Behavioural Advisory based on Hemma

In the analogue approach promoting solar panels, Nordea employees were trained to bring up solar panels at customer meetings. This is by far the most difficult challenge since it requires stepping out of their comfort zone and proposing green solutions face to face. The results show that only 10% of the bank advisors proposed solar panels in practice, which is a relatively low share. However, those who did were extremely successful in doing so, and client feedback from interviews shows that the bank is rated positively for its initiative in the green agenda.

Interviews with successful bank advisors reveal that they are genuinely interested in taking part in new solutions and proposals and that the enthusiasm for creating value for customers makes them propose green solutions. Thus, the steep behavioural barrier of taking on the part of energy advisor when being a bank advisor can be overcome, but the focus should be on the advisors who volunteer because of interest and FIs should not spend resources on training everyone.

Figure 78
Consent document used by FI for retrieving data (Page 1)

**Formål og samtykke**

Jeg afgiver samtykke til udveksling, brug og videregivelse af oplysninger i Nordic Energy Efficient Mortgages (NEEM) pilotprojektet og evt. deltagelse i efterfølgende interviews

**Baggrund**

FI NAME er partnerbank i et EU projekt, der hedder NEEM (Nordic Energy Efficient Mortgages). Danmarks Tekniske Universitet (herefter kaldet DTU) har udviklet en løsning, hvor DTU baseret på forbrugsudgifter, vejrdata, klimadata, og andre offentlige data er i stand til at komme med kvalificeret og underbygget bud på hvilke forbedringer en boligejer med fordel kan iværksætte på sin boligs "klimaskærm" – det vil sige den udvendige del af huset – for at opnå de største energibesparelser.

**Formål med piloten**

FI NAME ønsker at gennemføre en pilot, der tester boligejerens oplevelse af at deltage i og modtage forslag til energiforbedringer i hjemmet. Målgruppen for piloten er FI NAME medarbejdere, som bor i enfamiliehus i Trekantområdet og som modtager fjernvarme fra TREFOR. Antallet af deltagere i piloten er 30-40 boliger. Deltagerne vil efterfølgende skulle besvare et spørgeskema af ca. 10 minutters tidsforbrug, og kan efterfølgende give accept på deltagelse af et interview af ca. 20 minutters varighed. Begge dele omhandler medarbejderens oplevelse af værdien af de modtagne forslag til energiforbedringer og oplevelse af deltagelsen i pilotprojektet.

**Data og adgang hertil**

Data der indsamles, er elforbrug i kWh pr. time over 12 måneder og forbrug af fjernvarme MWh-tal og kubikmetertal (m3) og ejendomsdata der er offentlig tilgængelige i BBR eller andre steder.
Piloten kræver, at den enkelte medarbejder giver samtykke til, at NEEM-konsortiet må indhente energiforbrugsdata fra TREFOR og datahub for elforbrug. NEEM-konsortiet er FI NAMEs samarbejdspartner og udover FI NAME vil følgende partnere/deltagere i NEEM-konsortiet have adgang til data:

- Center Denmark, Vendersgade 74, 7000 Fredericia
- Copenhagen Economics, Langebrogade 1B, 1411 København
- Danmarks Tekniske Universitet (DTU) Anker Engelunds Vej 101, 2800 Kongens Lyngby
- Green Digital Finance Alliance, Route de Chêne 30A, C/O L&S Trust Services SA, 1208 Genève
- Behavioural Advisory c/o Jossi Steen-Knudsen, Tuevænget 1, 4000 Roskilde

**Anvendelse af data**

NEEM-konsortiet og dets deltagere vil anvende det indhentede data til at udarbejde en 'one-pager', en rapport, der viser det økonomiske potentiale ved at energirenovere huset. One-pagerne er skræddersyede til det enkelte hus, og sendes til deltagerne (FI NAME-medarbejderne) på mail.

Data fra one-pagerne anvendes desuden på aggregeret, anonymiseret niveau og inddrages i en samlet afrapportering til EU-kommissionen i forbindelse med projektet. Afrapporteringen vil være offentligt tilgængelig.

Confidential

Source: Behavioural Advisory

Figure 79
Consent document used by FI for retrieving data (page 2)

**Mit samtykke**

*Jeg giver hermed samtykke til at FI NAME må videregive mit navn, adresse og kontaktoplysninger til DTU og øvrige deltagere i NEEM-konsortiet – se deltagerne ovenfor – der kan indhente, bruge, bearbejde, udveksle mellem hinanden og videregive*

- *energi data, herunder elforbrug, fjernvarmeforbrug*
- *oplysninger om forbrugsudgifter*
- *ejendomsdata, som beskrevet ovenfor*

*til brug for*

- *udarbejdelse af rapport, one-pager, om mulighederne for at lave energiforbedringer m.m. i min bolig, jf. ovenfor,*
- *planlægning og gennemførelse af interview om pilot forløbet m.m., og*
- *rapportering til EU om forløbet af piloten/projektet.*

*Samtidig giver jeg tilladelse til at FI NAME som deltager i NEEM-konsortiet må fremsende spørgeskema, og evt. interviewe mig om forløbet af piloten/projektet, og anvende mine udtalelser – i anonym form – til rapportering til EU om forløbet og oplevelsen af piloten/projektet. Spørgeskemaundersøgelse og interviews sker i samarbejde med Behavioural Advisory. Jeg er bekendt med at rapporteringen til EU er offentlig tilgængelig.*

***Tilbagekaldelse af samtykke***

*Jeg kan altid tilbagekalde mit samtykke ved at kontakte NAME OF EMPLOYEE i FI NAME på tlf. nr. XXXXXXXXX eller på mail XXXX@FINAME.dk eller dennes kollega.*

*Udfyldes med blokbogstaver:*

| | |
|---|---|
| Navn | |
| Adresse | |
| Post nr. og by | |
| Telefon | |
| Mail | |

……………., *den* ……………….

------------------------------------------
*Underskrift*

Confidential

Source: Behavioural Advisory