Judith Thomsen • Ruth Woods • Nicola Lolli

SINTEF NOTES 31

# 1, 2, 3 Housing! Good, affordable and energy efficient housing for refugees

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## Preface

Prosjektet "1, 2, 3 Boliger! Gode, rimelige og energieffektive boliger for flyktninger" ble finansiert av Husbanken fra 2016–2018. Prosjektet ble gjennomført i samarbeid med Melhus kommune. Nøkkelpersoner fra Melhus var Tor Ingar Skjelvan Verstad, Bjørn Tuflåt og Folke Havdal.

Prosjektet er utført ved SINTEF Byggforsk, avdeling Arkitektur, byggematerialer og konstruksjoner, av forskerne Ruth Woods, Nicola Lolli og Judith Thomsen. Åshild Hauge og Øystein Rønneseth fra SINTEF Byggforsk har bidratt med kvalitetssikring av rapportens faglige innhold.

Vi takker Husbanken for støtte til prosjektet, Melhus kommune for bidrag og hjelp, og informantene for å ha stilt opp til intervju og vist oss sine boliger. Uten dere hadde det ikke blitt noe prosjekt!

Trondheim, 31.10.2018

| | |
|---|---|
| Jonas Holme | Judith Thomsen |
| Forskningssjef | Prosjektleder |
| SINTEF Byggforsk | SINTEF Byggforsk |

## Norsk sammendrag

Prosjektet "1, 2, 3! Boliger" har studert hvordan en bolig oppleves fra flyktningenes perspektiv. Flyktninger som bosettes i kommuner, får tildelt en bolig ved hjelp av kommunen. Kommunene har et ansvar for å stille med plass å bo for de som klassifiseres som vanskeligstilte, herunder regnes også flyktninger som skal bosettes i kommuner: "De som ikke selv er i stand til å skaffe seg en bolig og bli boende, skal få den hjelpen de trenger. Ingen skal måtte gjøre seg fortjent eller kvalifisert til å få hjelp. Alle må bo, og med riktig hjelp kan alle bo (KMD, 2014)." Boligen skal være en god og verdig plass å bo og i prosjektet ønsket vi å undersøke hvilken type bolig flyktningene i Melhus kommune har fått etter de ble bosatt. Vi har gjennom prosjektet intervjuet representanter fra flykninger bosatt i kommunene og representanter fra kommunens bosettingskontor og bygg og eiendom. Fokuset var tildelingsprosessen, tiltakene de setter i gang når en ny person/familie skal bosettes i Melhus kommune og bopreferansene til flyktningene.

Videre ønsket vi å se på energiambisjonsnivået kommunen legger i boliger som bygges for vanskeligstilte. Hypotesen var at det blir vanskelig å legge seg på et høyt ambisjonsnivå når det gjelder energieffektive boliger fordi man ønsker å holde et lavt kostnadsnivå. Vi har sett på andre løsninger som kan velges og vi anslår (mer)kostnader for disse løsningene.

Interessen for hvordan håndtere bosetting av flyktninger i norske kommuner har økt siden 2015, hvor det har kommet mer enn 30 000 flyktninger til Norge (SSB, 2016). Flyktninger som har fått innvilget opphold vil bosettes i kommuner utover hele landet. Få tilgjengelige boliger på utleiemarkedet og mangel på rimelige boliger på boligmarkedet kan være utfordrende for kommunene når det gjelder bosetting.

Det ble gjennomført intervjuer med 6 flyktninger bosatt i Melhus kommune og intervjuer med 2 representanter fra bosettingstiltaket.

Intervjuene viste at informantene var fornøyd med boligtilbudet. Selv om noen har ønske om å tilpasse boligen mer til deres preferanser etter hvert, er det i første omgang viktigst å etablere seg på Melhus og i det nye livet.
Samtalen om boligens utforming viste at beboerne var mest opptatt av størrelse og antall soverom. Detaljer som materialer og farger ble også kommentert og det er disse elementene som oppleves som en forskjell til hjemme landet. Også størrelsen på boligene er noen ganger mindre enn det informantene var vant til hjemmefra hvor i noen tilfeller flere generasjoner deler boligen. Boligene var lokalisert ulike plasser på Melhus. Informantene ønsket ofte en sentral beliggenhet i forhold til butikker og service funksjoner siden de ikke hadde bil. Flere skaffet førerkort og bil for å bli mer fleksible. Beboerne var opptatt av å holde energibruken lav for å spare kostnader for strøm.

Melhus kommune har stort fokus og høy bevissthet rundt bosetting av flyktninger i kommunen. De har etablert sin egen "standard" som inkluderer boveiledning og tett oppfølging i startfasen. De er også opptatt av å gi flyktningene et hjem.

Energianalysen tok utgangspunktet i et byggeprosjekt av Melhus Kommune. Det ble simulert flere alternative teknologier for dette prosjektet, inkludert varmepumpe, solceller, solfanger. For utvalgte løsninger som viste potensiale for lavest levert energi, ble de tilhørende kostnadene estimert. Analysen kom fram til tre scenarier hvor kostnadsnivå og energisparepotensiale står i et slikt forhold til hverandre at det kan være lønnsomt å implementere både for kommunene og beboerne.

## Contents

# 1. Introduction

The main aim behind the 1,2,3! Project is to study how a dwelling is perceived from the perspective of the refugee residents who have been given permission to settle in Melhus Municipality. The municipality has the responsibility to provide refugees settling in Norwegian communities with a residence. The municipalities have a responsibility to accommodate those who are classified as disadvantaged, and this includes refugees: *"Those who are not self-sufficient to obtain housing and living, will receive this assistance. No one needs to earn or qualify for help. Everyone must live and with the right help everyone can live"* (KMD, 2014). The interest in how to handle refugee settlement in Norwegian municipalities has increased, because in 2015 more than 30,000 refugees applied to settle in Norway (SSB, 2016). Refugees granted residence have been and will continue to be settled in large and small municipalities throughout the country. Municipalities increasingly rely on the rental market in the private sector. In 2016, two of three refugees were housed in privately owned housing (Søholt et al. 2018).

Finding appropriate refugee housing is in general a challenge for municipalities in Norway; both in public and privately owned housing. The report provides an example of solutions within Melhus municipality. In addition to the broad focus in housing quality and the framework around settling the refugees, what is known here as "the welcome to Melhus standard", the report analyses in detail energy use within refugee housing. The initial idea with the focus on energy use was strengthened throughout the project since the topic of energy use stood out as a common point of concern among all respondents of this study.

The project consists of two main parts:

1. Housing quality: The accommodation provided for refugees should offer a good place to live and the 1,2,3! Project has therefore investigated what type of housing is provided for refugees in Melhus Municipality and resident satisfaction. We have interviewed a group of six refugees who have been given a residence permit and have settled in Melhus. They have been asked about the settlement process and their housing preferences. In addition, we have interviewed municipal representatives about the settlement process and the measures taken when a new person or family arrives in Melhus.

2. Energy analysis: The energy ambition in homes provided by municipalities has also been analysed. The project has considered buildings whose construction is under planning and buildings rented for refugees. The hypothesis was that it would be difficult to get a high level of ambition in terms of energy efficient housing because a low-cost level was important. We have considered other potential energy solutions and have estimated the cost of these solutions. The aim was to propose energy and cost-efficient solutions for future housing projects.

There are a number of reasons for the association of these two themes in this report:

- The report is intended as a tool to support the development of appropriate housing.
- Household energy use should be reduced if we are to achieve CO2 reductions required on national and local levels.
- Energy use is associated with comfort levels and this has implications for housing quality.
- Electricity bills can be a challenge for households with low incomes which can have implications for housing preferences.
- Finally, good examples are useful when planning social housing for the future.

In addition, this intention to analyse energy ambitions in future housing concepts was supported by the interviews with informants among the refugees in Melhus. They point to expensive energy use and saving energy to being a common concern among refugees within the community.

## Project background

### Housing in Melhus Municipality

Approximately 16,000 residents live in Melhus, which is located in the Southern half of Trøndelag County Municipality. The Municipality is located just south of Trondheim and includes seven smaller communities within its boundaries: Hovin, Lundamo, Ler, Kvål, Melhus, Korsvegen and Gåsbakken. The railway and the E6 motorway both travel from north to south through the Municipality.

In 2005, the E6 motorway was relocated outside of the centre of Nedre Melhus. In connection with this process, the old E6 was converted into a "green street". This was a part of the process of creating a better physical and social environment in the town centre, and at the same time allowing it to develop a more urban character. The redevelopment also included the new housing.

The population is growing. The proximity to Trondheim is one of the factors that makes the Municipality attractive; this also applies to refugees settling within the community. Popularity has led to pressure on the housing situation. The Municipality has defined a number of areas for development with a capacity of approximately 5,600 residential units. The character of the houses in Melhus is changing. The community is moving on from a dependence on detached housing to investing in the construction of apartment buildings. The Municipality has allocated areas for the construction of social housing.

### Refugee settlement

This section summarises strategies for the housing of refugees who have been awarded permanent residence in Norway. This is primarily based on the Norwegian Whitepaper 30 from 2015. Supporting information is provided by reports presenting measures introduced in other Scandinavian lands. The main subject is on housing solutions. Other factors relating to integration, such as language courses and social/cultural activities are not in focus. The final part of this section presents examples from research about refugee settlement that took place in other communities in Norway.

The background for the project was the European refugee crisis in 2015-2016. In 2015, 31 145 refugees came to Norway, 20 935 to Denmark and 162 450 to Sweden. These were the highest numbers ever registered. In 2015, 50 000 refugees were expected to come to Norway each year and into the foreseeable future (Meld. St.30 2015-2016). The increase in the number of refugees was expected to have broad implications for the social housing situation in Norway and the rental market. International agreements mean that the projected increase is no longer a reality. In 2016 – 700 000 immigrants were resident in Norway – 150 000 born in Norway with immigrant parents – 16% of the Norwegian population had immigrant background.

### Meld. St.30 – Settlement

"*Anyone with legal residence in Norway can settle in the Municipality they themselves choose. This does not apply if you rely on financial assistance from public authorities. People who have applied for protection and who have been granted a permit to stay in Norway receive public assistance to settle in one Municipality*."

Refugees are provided with housing in the Municipality where they settle. Settlement with public aid is provided by the state (IMDi)[1]. The settlement of refugees by municipalities is

[1] Refugees receive only one offer to settle in a Municipality and the decision cannot be appealed. If the refugee says no to the Municipality where settlement is offered, the refugee is required to move

voluntary, but it does require continual follow-up by municipalities ((Meld. St.30). Refugees and reunited families have rights according to the introductory act cf. Chapter 5. The Municipality has a duty to offer refugees an introductory program that includes Norwegian and social science classes. Participants in the introductory program are also entitled to introductory benefits.

Refugee settlement goes through three main phases – reception, transition and permanent settlement (Kassyie 2002b). "*The timing and kind of settlement support and service provided by each stage of the refugee settlement will largely determine the extent with which refugees will be integrated into the host community and realise their potential to meaningfully participate in public life and in building greater community cohesion. This makes housing a primary issue of refugee protection and integration*." (2002b).

Housing provides the framework for work and participation in society. The settlement of refugees is characterised by uncertainty with regard to how many homes are required at any time and the type of housing needed. There is already a need for more rental housing in both large and small communities, both municipal and private housing. It is estimated that from 177,000 and 282,400 people struggle with the housing market in Norway. People who rent housing, such as refugees find the housing marked particularly hard to deal with. Couples without children and the elderly struggle to a much lesser degree within the housing market[2]. Socially disadvantaged on the housing market is defined as persons or households who do not have the opportunity to acquire and/ or maintain a satisfactory living situation on their own (SSB 2017). The use of the private rental market is increasing, and this is one of the reasons Norwegian municipalities managed to settle so many refugees during and directly after the refugee crisis in 2015 (Søholt et al. 2018). Bergen Municipality has formalised its role with a safety agreement that supports the rental contract. Municipalities can guarantee against property damage (Meld. St.30). However, the rental market varies between municipalities, and in some communities the rental market is smaller. Refugees can experience that they are competing with other groups in need of housing, such as migrant workers (Woods et al. 2017). Other options are municipalities building their own houses, entering into long-term agreements with private developers, or buying apartments in projects that are under development. Municipalities and private developers can apply to the Housing Bank for basic loans and grants to buy or build homes to be used by municipalities. Grants to build rental housing is a high priority within the Norwegian government and the amount set aside for grants has increased since 2013. In 2014 and 2015, 2,900 homes received grants. In 2016, the Housing Bank has committed to providing grants for approximately 2,000 homes (Meld. St.30). Although the housing situation in Norway and other Scandinavian countries is under pressure, there would seem to be even greater pressure in countries outside Scandinavia where housing is understood in relation to homelessness, either you have a house/ residence or not, the quality of housing is not mentioned. Housing is however a key element in countries dealing with refugee settlement, it affects refugee mobility and integration (Mulvey, 2015), having implications for stability and access to services and employment.

The increased number of refugees means increased pressure on integration. The Norwegian introduction law provides a framework so that refugees can qualify for working life and/or education. In recent years 70% of men and 50% of women who participated in the program found work or a place to study within a year of its completion. In Norway, the move from refugee centres for those who have been given permanent residence goes too slowly. In

out of the refugee centre and receives no government help. The right to introductory program and introductory benefits are lost (30).

[2] The actual number depends how the numbers are analysed and depends on who is included in the definition of socially disadvantaged on the housing market https://www.ssb.no/bygg-bolig-og-eiendom/artikler-og-publikasjoner/hvem-er-utsatt-pa-boligmarkedet

2015, three out of every ten refugees awarded permanent residence were waiting for a municipality to offer them a place to live (Harbo 2015). The Norwegian model allows municipalities to decide themselves if they want to receive refugees, their own sovereignty is important to them and their population. The settlement of refugees is dealt with by Municipal Councils and is thus well anchored on a political level (Gran 2014). Waiting in refugee centres for a long period hinders integration, but there is scepticism to the coercion practiced in Denmark, and the freedom to choose practiced in Sweden. The Norwegian association of local and regional authorities (KS) proposes that the best solution to speeding up the settlement process is a better framework for the purchasing of dwellings (Gran 2014).

There is pressure on the integration of refugees in Norwegian municipalities, but Søholt et al. (2018) state that this does not appear to have taken place at the expense of housing standards. The overall standard remains satisfactory; a greater challenge is finding housing that is both large enough and affordable for large families. Avoiding the use of co-housing or housing cooperatives for single families is also an issue that the smaller municipalities are dealing with.

**Sweden**

Refugees in Sweden can choose themselves where they want to live. This model has been in place since 1994. A variant of the Swedish scheme is practiced in a number of Norwegian municipalities – an agreed settlement. This means that refugees find housing themselves and enter an agreement with the Municipality they settle in. However, unlike the Swedish model, the Norwegian Municipality must approve the dwelling. It is estimated that approximately 12 percent of all settlements in Norway now take place in this way (Harbo 2015). The Swedish model does have negative side effects because the refugees tend to settle together. This can cause problems for the social services, schools and the surrounding neighbourhoods in "popular" municipalities. There are housing estates in Sweden which have a population of almost 95% immigrants, schools with a large number of migrant children and little integration in the Swedish community (Gran 2014).

**Denmark**

The Directorate for immigration in Denmark distributes refugees over five regions. Within these regions, there is a certain amount of self-determination about where the refugees will be settled, but municipalities cannot refuse to receive them. The aim is to achieve greater geographic distribution. Norway has been negative to this model because it means state coercion (Harbo 2015). The Danish model has achieved a quicker settlement process, but integration and employment is low (Gran 2014).

**Housing refugees in rural Norway**

Sjøholt et al., (2012) conducted qualitative and quantitative surveys on refugee housing in three Norwegian municipalities, Vestvågøy, Tynset and Haram. The report emphasizes that housing conditions are different in district municipalities than in big cities. In rural municipalities residents live in detached houses, housing prices are lower than in urban areas and the neighbourhoods are not characterized by high concentrations of immigrants. The report points to several trends that are also relevant in Melhus:

- There is pressure on the housing market in the “urban” areas.
- Refugees live in the larger urban centres or near major industrial sites.
- Fewer refugees own their own car and a central location becomes important.
- There are a limited number of rental homes and several refugees are interested in buying their own accommodation.
- It takes longer for refugees to finance loans for their own housing than it takes for migrant workers.

Sjøholt et al. emphasizes that if we are to help immigrants into the housing market, it is important to give advice about loans and housing purchases in general. They have also registered that refugees are often perceived in a more positive way after they have invested in their own home (Sjøholt et al. 2012). This report was followed up in 2018 and the trends are still relevant (Søholt et al. 2018). It is for example still important for refugees to live close to the main urban centres, there is more pressure on the large urban centres, but at the same time there are differences in the housing market which means small communities are dealing with different challenges to those in the larger towns. It is easier in smaller municipalities to find large single-family housing. However, in smaller municipalities it is a challenge to avoid locating refugees in the same areas of the community, as is finding accommodation for single people.

**The Frøya example**

In 2016, SINTEF Byggforsk completed a project that had refugees and migrant workers on the Island of Frøya as the main target group (Woods et al. 2017). The aim was an analysis of housing preferences for new residents on the island. The background for the project was the planned development of thirty new homes for the socially disadvantaged on Frøya.

The target group for the housing on Frøya is single male refugees. It is challenging to find suitable housing for refugees on the island. The Municipality uses the private housing market and refugees are competing with labour migrants and others (ethnic Norwegians). A number live in housing collectives, but not everyone wants to live in this kind of accommodation. There are currently few alternatives, and the refugee consultant of Frøya stated:

> *"The problem on Frøya is that there is soon no room to settle more people. There are no locations for Norwegian and Social Studies courses. [...] Frøya people are quite positive about taking in refugees. The problem is that we are having to use housing collectives. We are renting entire detached houses, so they have to share kitchens and bathrooms. A housing collective can be a suitable alternative, but it can be difficult for families and people from certain cultures to share their private space with others."*

Preferences regarding the existing environment and architecture were important during the planning and development of future housing on Frøya. In 2016, five homes intended for refugees were completed on Frøya. These currently house refugee families and ethnic Norwegians.

## 1, 2, 3! Research questions

Overarching question: How can we, when developing a new residential concept, safeguard the needs and preferences of a disadvantaged target group, while at the same time provide future-oriented housing with regard to energy ambitions and quality?

The follow-up research questions for the work with housing quality are:

1. How do the refugees of Melhus reflect upon their Norwegian dwelling?
2. How do they describe cultural differences between the dwellings they were used to and the Norwegian dwelling?
3. What are other aspects they are concerned with regarding their dwelling in Norway? (e.g. location, appliances, electricity price, quality, indoor temperature, etc.)

Energy analysis:

4. What energy and cost savings are achievable by implementing energy saving measures beyond the TEK 17 requirements?

## Implementation and methods

The methods applied are: (1) the interviews with the refugees and (2) the analysis of energy efficiency solutions. The methodological description is divided along the same two lines.

A start-up meeting with Melhus Municipality's settlement office was used to discuss the project aims and the support required. For part one, Melhus Municipality established contact to the interviewees and arranged the meetings. The interviewees are refugees who have settled in Melhus Municipality. The aim was to meet a cross section of the demographic group found in Melhus, this included women and men, families and single persons, from different countries.

Parallel to the interviews we investigated technical solutions chosen in a housing project with 8 dwellings that is under development for disadvantaged residents in Melhus Municipality. The goal was to investigate the possibilities for increasing the technical standard to a more energy-efficient solution, whilst remaining within a reasonable cost framework. Simulations of different energy efficiency solutions and their costs were conducted and analyzed. However, although the project believed that focus on energy effective housing solutions for the disadvantaged groups of the population is an issue that should be highlighted during the development of future housing solutions, we did not know if energy use or energy saving would be a factor that was important to our informants in Melhus. The interviews described below were intended to uncover issues that our informants considered important, energy was not the only issue discussed (appendix 1). Interviews showed that the refugees that settled in Melhus were interested in how much their electricity bills were each month and in saving cost for energy use. Developing future housing solutions that help refugees and other disadvantaged groups to save energy and by that to reduce monthly expenses, seems therefore particularly pertinent.

## Qualitative methods

### Interviews

Interviews were completed with one member from six households during the summer 2017 Table 1. The interviews took place in Melhus Municipality's settlement offices. Each interview lasted approximately 45 minutes. The main language was Norwegian but was supplemented occasionally with English. We also completed a group interview with two municipal employees. Each interview took the form of an open structured conversation. For interview guides, see attachments. Five of the interviews were recorded (one informant asked not to be recorded). The interview data is anonymous.

Qualitative interviews are a preferred method when there is not only one answer to a question and when the intention is to inquire about people's personal experiences and motivations. The information about the lifeworld of the interviewees revealed in interviews, is detailed and provides explanatory information about personal points of view. May (1993) describes interview techniques as one of the main research methods in the social sciences.

*Table 1: Overview of interviews. For a more detailed overview of the six households, see Table 2.*

| Date | Number of interviews | Role |
|---|---|---|
| 09.06.2017 | 3 | Refugee |
| 15.06.2017 | 3 | Refugee |
| 22.08.2017 | Group interview | 2 municipal representatives |

**Home visits**

Early in 2018, two of the interviewees were followed up with home visits to enable a more profound understanding of how the refugees live in Melhus. This was intended to be a sample and the choice of home was based on information received during interviews. In one household, we felt that we lacked a clear picture of how the interviewee lived and in the other household the interviewee’s enthusiasm for his home made us curious. The visits enabled us to take pictures and talk informally about the interviewee’s homes within the context discussed. The two houses were in different parts of the Municipality. They were physically different, and the number of household members was different:

1. Row house from the 1990’s, three bedrooms, heated by electric panel ovens and a wood stove. Three household members.
2. Detached house built around 2015/6, four bedrooms, heated primarily by heat pump and underfloor heating. Six household members, although oldest “child” is studying and does not currently live at home.

**Limitations**

A small study like this has limitations when it comes to the number of respondents and who the respondents were. Six households were included. The municipality helped us to organize the meetings. The respondents had to be willing to talk to us, and importantly they spoke either Norwegian or English. According to the municipal representatives associated with the project, the combination of language skills and a positive attitude often went hand in hand.

The type of housing the six households received when moving to Melhus was various and is difficult to compare. They live in row-houses, detached houses and apartments. Some rent from the Municipality and some from the private market. Interviewees lived in the town centre and others lived on the outskirts. Household constellations were also various, some lived alone, others with their families. They came originally from different parts of the world and their professional careers and personal preferences varied. Common traits were difficult to identify.

This project is about housing preferences and “we” the researchers have collectively a number of years of experience working with buildings and have an above average interest in houses. Even with our enthusiasm and understanding about the issues we are talking about, it was not always easy during interviews to gather information about the topic. For example, what is a house or an apartment, what is it that defines the format or limits its boundaries? Within the northern European context, this seems obvious, but our informants were not used to the Norwegian/ English terms and the differences or details were often not important issues for them. It became clear that for our group of interviewees housing preferences were not something they had much reflected over and this made gathering data about it a challenge.

## Quantitative methods /simulations

To establish the potential energy use and running costs associated with the housing available for refugees, different energy efficiency solutions have been applied to the buildings in

Melhus. The yearly energy use and the running costs over a 25-years and a 50-years period have been estimated.

To calculate the annual energy use of the building in Melhus, the energy simulations of different energy efficiency solutions were performed using Ida-Ice v.4.7, which allows a dynamic analysis of the thermal exchanges between the building and the outdoor environment. The analysis was performed based on a Typical Meteorological Year in Trondheim, by using the closest weather station available (Trondheim Værnes). The energy use for heating and ventilation is done by calculating the building's energy balance for each calculation time step (1 hour, for a total of 8760 hours in one year). The building energy balance is calculated in Ida-Ice by considering the thermal losses through the building fabric, via the ventilation and infiltration, and the thermal gains due to solar irradiation, operation of equipment, the artificial lighting and the human metabolism. The energy use for the other building end-uses (lighting, equipment, and domestic hot water) is based on the values given in the NS 3031:2014. Electricity is assumed to be the only energy carrier needed to operate the building.

The calculation of the energy cost and investment cost of the different energy efficiency solutions is performed by multiplying the yearly energy use by the electricity cost for residential buildings (including the power grid cost). The initial investment cost and the replacement cost given by the implementation of the different energy efficiency solution is based on statistical data from the NVE. A discount rate is attributed to the future investment cost, due at the time of replacing the technical components. The future variation of the electricity cost is not included in the cost calculation.

## 2. Refugee housing: the Melhus approach

### Six households

*Table 2. The following table gives an overview of the interviewee`s family situation, the type of dwelling they live in, the number of rooms, approximate monthly rent, and their preferred indoor temperature. The respondents were from the counties of Syria, Kongo, Sudan, and Eritrea.*

| Inhabitants | Years in Melhus (in Spring 2018) | Type of dwelling/ ownership | Number of rooms | Approx. rent/ month in NOK | Residents` estimated preferred indoor temperature |
|---|---|---|---|---|---|
| 1 adult woman, 2 children 10 & 12 years | About 4.5 years | Row house with basement ca. 110 m2 Wood stove. Municiple | 3 bedrooms Kitchen-living room Laundry room+ bathroom | kr 9600 | |
| 2 adults 4 children, 19 (does not live at home) 18, 15 & 10 | About 3 years | Row house 2 floors. ca. 120 m2 + carport & outside sorage. Joint heat pump & ventilation system. Municiple | 4 bedrooms 2 bathrooms Kitchen-living room | kr 13000 | |
| 2 adults 1 child - 6 months | About 4 years | 1st floor apartment in a row house + outdoor storage. Totally rehabilitated. Municiple | 1 bedroom Bathroom Kitchen-living room. Kitchen fan | Pr. 1.7.17: kr 6200 Offered larger apartment kr 9000 (too expensive) | 22-23$^{O}$C |
| 1 man | About 4 years | Basement apartment 60 m2 in old detached house. Kitchen & bathroom fans. Private | 1 bedroom Bathroom Living room with kitchen area. | kr 6000 incl. electricity | 21 $^{O}$C |
| 2 adults 2 children 2-5 years | About 4 years | 1st floor apartment in small 2-story block. 84 m2. Indoor storage. Municiple | 2 bedrooms, bathroom Kitchen-living room with sliding doors between | kr 7600 | 19-21 $^{O}$C |
| 1 man | About 2 years | Apartment in 5-story block from 2015 40m2 Private | 1 bedroom Bathroom Kitchen-living room | kr 8 500 | 18-20 $^{O}$C |

### Interview data

Finds resonating with other research

The next chapter summarizes the interview material. The interview guide with questions for interviews with both the refugees and municipal representatives are available in the appendix. The feedback from informants resonates with existing research done about housing for refugees and migrants in Norway (Søholt et al. 2014 & 2018, Woods et al. 2017). The challenges that both refugees and representatives from the municipality are dealing with are represented within other communities. The findings in this report therefore have value in other Norwegian municipalities. Examples about energy use that complete this section about the interview data, are an important supplement to the research about housing for the socially disadvantaged in Norway.

**The dwelling**

> *"Amir" rents privately. His apartment is on the ground floor of a single-family house and was furnished when he moved in. Amir is perhaps the least satisfied of our respondents. He told us that the furniture was old and not his style. However, he is at the current time satisfied, but plans to improve his housing situation later. Other things are more important him; he can receive visitors, he is safe, has a job, and has had time to become established in his new life. The housing situation can wait as long as everything else works now.*

Amir's attitude is that other things are more important than the dwelling, and this is a common trait found among all the refugees that we spoke to. The interviewees did not have very detailed reflections about housing quality of their dwelling. They focused mainly on housing size, the number of rooms and location when describing their dwelling. The respondents we talk to coped well with the organization of the floor plans of their Norwegian dwelling. During the conversation we learned however, that all had also reflected on material use or colour schemes which are often different to what they were used to from their home countries. Several intended to make changes to the interior at some later date, or to blend in elements that they were used to from their home countries once they have settled properly (see also section on cultural differences).

When talking about the dwelling`s interior plan or layout, conversations often paid attention to the kitchen and they found positive qualities in the solutions their homes. "Mehmet" thought that it was a satisfactory solution that their kitchen has a sliding door that can be closed sometimes. It helps to avoid odours spreading to the living room and sometimes, it can be convenient to keep the children out of the kitchen. Milan reported that they have an "American kitchen" where one side of the counter is open towards the living room. He likes this partly open solution and his wife enjoys being able to watch TV while cooking. "Nanna`s" kitchen is in a separate room, however the door has been removed, so it is open and there is good contact with the living room.

*Pictures 1 and 2: two different kitchens in the respondents` homes. Pictures by: SINTEF Byggforsk*

All interviewees provided us with a general description of their dwellings in Melhus. Interestingly, the formal terms to describe the type of housing, e.g. row house or detached house, were sometimes unclear to the interviewees. Either because the Norwegian terms were not clear to them or they were not used to this particular type of housing. This meant that the description collected by us had to be confirmed or adjusted with help from the municipal representative who has visited all the dwellings.

When we asked what kind of housing the Municipality should offer to future newcomers, Amir answered, that it should be varied, as it is today in Melhus. People living with families have diverse needs and the housing offered to them should reflect this. This implies that what is acceptable to single people such as Amir may not be functional to a family with children.

The format of the dwellings in Melhus differed as did other factors relating to the interviewee (see fig. 2), and the responses to our questions therefore vary. However, some common issues were noted:

1) The dwelling was regarded as satisfactory and moving to a new living situation in Melhus was a positive experience. The overall attitude to the dwelling and the particular solutions was also positive.

2) The kitchen is a room that was important to the majority of households.

3) Technical terms are difficult to understand and/ or explain. This can challenge the ability of refugees to state their preferences.

**The differences**

> *"Milan" said that he does not have a problem sitting together with the ladies, however he knows some other refugees that are more concerned about this.*

Plan layout in Norway differs sometimes from what the respondents were used to in their home countries. For instance, in some cultures, the female and male members of a family have different areas in a dwelling. The refugees we interviewed had no difficulties with adopting to the Norwegian plan layout. However, as Milan`s quote above indicates, are other refugees sometimes concerned with this. This perception will differ from culture to culture and as well depend on how strict societal and religious habits from home countries are maintained after moving to Norway.

Milan told that he is used to a more collective lifestyle from his home country. Often, they have houses built for two generations since it is common to live together not only with the nuclear family. In Norway, the size of the dwellings usually does not allow to house several generations. Tassim came to Norway with his extended family (of 3 generations). Melhus had to provide them with 4 different dwellings instead of one.

Material use in exterior and interior is a major difference between the Norwegian buildings and their home country dwellings as all the respondents pointed out. None of them was particularly used to wood as a cladding-, surface- and construction material. Most of them were used to concrete or brick constructions, tile- and stone surfaces. What is important to note, is that there are differences in maintenance practice between these materials. Milan told us that he soon learned "*not to use lots of water*" to clean the wooden floors in his home in Melhus. The Municipality has focus on explaining how to maintain and clean wood surfaces, e.g. do not use water as commonly used on tiles and stone floors. The materials used in Norway give a lesser association with a feeling of home for the respondents we talked to. If they were one day able to build their own house, some told us that they would combine the Norwegian materials with some of the materials they were used to from their home countries, such as stone and tiles. Hauge et al. (2015) reported the same challenges with maintenance of new or typically Norwegian materials in refugee reception centres.

Colour schemes used in Norway also differ. In cultures where respondents came from it was more common to have colourful interior, while in Norway the exterior is often colourful while the interior walls are white or greyish. Building materials in the respondent`s countries of origin had often natural material colours such as stone, clay or masonry or the local regulations recommended a homogenic exterior colour scheme.

Appliances such as mechanical ventilation systems and heat pumps are present in several of the dwellings and were not unknown to most respondents. They were used to air conditioning in their home countries. Underfloor heating in the bathroom was something new and was perceived as strange by one of the informants. Milan wondered how one can have electricity in a wet room? This seemed dangerous and unnatural to him and he never uses the underfloor heating in the bathroom.

**Location and transport**

The interviewee`s dwellings were located all over Melhus. They were not located together with other housing for refugees. They were living in row houses or housing blocks, side by side with their Norwegian neighbours. Søholt et al. (2018) noted that although municipalities try to locate refugees as centrally as possible, to avoid isolation, there is a general policy among municipalities to aim towards the distribution of refugees in “ordinary” neighbourhoods. They do not want too many refugees living within the same area.

A preferred location by most respondents was close to services such as schools, kindergardens and grocery shops. If these functions cannot be accessed by walking, it was emphasised that proximity to bus stop is important.

In one case, the bus stop was a 13 minutes' walk away. Getting around and grocery shopping were perceived as time consuming. This respondent got a driver`s licence and bought a car this year. Another respondent told us that he was used to driving and he was not used to walking, especially when the weather is bad. Three of six interviewees had a car. Other respondents were little concerned about walking or living within driving distance to school. A distance of 2 km to the centre of Melhus was described as a walkable distance.

*Picture 3 and 4: view of the local surroundings from two of the respondents` homes. Picture by SINTEF Byggforsk.*

### Electricity use and cost

**Energy stories from the home visits**

*Nanna: The house was warm. Nanna was wearing an armless t-shirt. We talked a little about how much she spends on electricity every month. Nanna was clear that, "Electricity is expensive in Norway". She has tried to use less electricity, but it did not make much difference to the bill. One winter she tried to heat the house just by burning wood but getting enough wood can be a challenge because her home is so far away from the shops. If you want to buy a lot of wood, then you need access to a car. Nanna now has both a driver's license and car.*

*Milan: The house was new when they moved in. Milan had painted the walls himself, just like his Norwegian neighbours. We did not talk about how much it cost to live there or how much the electricity cost during the visit, but Milan had previously told us that he thought that electricity was expensive in Norway. They spend a little more during the winter. We were told that the house had underfloor heating and ventilation systems. In addition, the family has installed a heat pump that they can use for cooling in the summer. The Municipality paid for the heat pump because the family had applied for support and because Milan had painted the exterior walls.*

The two energy stories illustrate the differences in housing type, heating source and challenges associated with living in the homes provided by the municipality. No one we spoke to complained about being cold in their homes, but the topic of energy use stood out as a common point of concern among all interviewees.
In general, electricity cost per month was described as high. All interviewees stated an approximate sum for the electricity costs they pay each month. It was however unclear to them if this sum included grid rent. The division between grid rent and cost for energy use in the energy bill were difficult to understand. A municipal representative was given the opportunity to read and reflect over the overview that we had made based on the costs that the six households estimated. He stated that, *"they do not understand the energy pricing. They do not see the difference between grid rental and energy use."* He gave an example from one of the six households *"For instance, in one house they have both balanced ventilation and a heat pump and only two external walls. The cost for electricity use is on average kr 1400 per month."* However, once grid rental is added to this sum, the total is expensive.

The respondents told us that they focused much on keeping their energy bills low. Actions included keeping a reasonable indoor temperature during winter and switching of heating / underfloor heating during the warmer months. Average indoor temperatures stated by the respondents (we have no proof by measuring) were about 19 - 22 ºC during winter. They stated that these temperatures were comfortable. This is lower than the common measured and preferred indoor temperatures found in Norwegian households during winter, where an average temperature of 22- 24 ºC was found in the evaluation of new housing projects (Thomsen, et al. 2017).

Mehmet told us that he sometimes asks his spouse to put on a sweater instead of increasing the heat pump setpoint to 25ºC. He does not want her to get used to the possibility of having warm indoor temperatures. Saving money is clearly an incentive to save electricity. They cannot influence the rental costs, but they can influence the electricity bill.

Nadira thinks that it is very expensive to live in Norway, especially the electricity bill. They do not use much, mostly for lighting and the washing machine. They switched off the electric panel heating in April. She told us that it is warm enough in the dwelling (flat in a block); she estimated about 22 ºC. Nadira and her husband also turned down the offer to move to a bigger dwelling because this would mean an increase in rental and electricity costs.

## Municipality: «Welcome to Melhus standard»

### Emphasis on human care

> *"There aren't many municipalities that have a housing and settlement office like the one we have in Melhus. We have a number of people who get the home ready; they set up furniture and replace countertops."*

There is a lot of pride about what the two municipal representatives called the Melhus Standard. The Municipality places a lot of emphasis on how refugees are received when they move into the community, "It may be that we spend more on wages than we do on the homes, but warmth (human interest/ care) is important. It is part of the welcome to the Melhus standard." In 2016, 740 refugees and reunited families settled in Trondheim. There is pressure on the larger cities to receive a greater number of refugees. In comparison, Melhus accepted fifty refugees in 2016. The two municipal representatives were conscious of having the resources to deal with refugee settlement in a "warm" way, "Melhus is well staffed in relation to Trondheim". Refugees reception (who, when, language and social courses) and settlement are coordinated in Melhus. There is a short physical distance between offices and according to our two representatives a good collaboration. The settlement office also provides housing advice – they show them how to use the home, how clean it and how to do things like reading the electricity meters. Melhus Municipality has developed a list that states what is included in housing guidance. The municipal representative's faith in the Melhus standard was reflected in the feedback from the six interviewees about how they were received into the community.

### Integration

Melhus aims for the integration of the refugees into the community. There is a maximum of three to four houses in each housing estate with refugees. Integration is also about making them feel welcome, giving them support during the first confusing days and following this up afterwards. There is a lot of follow up around the new Melhus residents; this is based on the larger and smaller details. This includes the human resources spent on this phase and on what they put into the home before the refugees arrive,

> *"When you open the door for the first time you will meet a home. We put a tablecloth on the table. We are all about the little details. You should feel warmth when you arrive. It costs almost nothing to create a home, to make a difference."*

Creating this difference is about more than the tablecloth. Providing enough human resources is of primary importance. The Municipality spends time making sure that individuals and families have what they need, approximately eight hours per day during the first two weeks, *"We arrange the first meal. It may be scary to go to the store."* What is included in the meal is pre-established based on experience. Chicken, rice and salad has become a standard, something that the majority of different cultural preferences can accept. Neighbouring municipalities have different practices with regard to what the supply the refugees. Melhus has faith in recycling and buying second hand furniture and the furniture is in place when the refugees arrive. Some municipalities supply new furniture and others expect the refugees themselves to find their own furniture.

*Picture 5 and 6: impression of interior of the homes of two respondents. Picture: SINTEF Byggforsk.*

**What are main challenges?**
The emphasis in Melhus is on what works. They know that they cannot help everyone, but the general feeling is that their recipe works, *“There is always someone who is difficult, but people tell us that they are content”*. The refugees are only supplied one home by the Municipality. If they are dissatisfied, they have to find a replacement themselves. This is a general rule for Norwegian refugee settlement and not just the case in Melhus. There are examples of refugees in Melhus who live in cramped conditions. This was due to the price of renting a home. According to the municipal representatives, the majority of refugees do not place much emphasis on housing quality; they are more concerned with location. Unfortunately, rental prices are higher in the town centre. Our six interviewees told us the same thing, they preferred to be close to the town centre, but if there is a good bus connection or they have a car then living outside the town centre is acceptable.

The housing market in Melhus is changing. According to the municipal representatives, the rental price is on its way down. The Municipality supplements its housing stock by renting on the private market. It is also developing houses. At the time of the interviews there were 30 new homes for the socially disadvantage under development in Melhus. There is according to the two representative no danger of there being too much social housing within the municipal building stock. Houses could in theory also be rented to people outside the group of socially disadvantaged. Housing is profitable for the Municipality. It is more profitable to buy a home than to rent from the private market. During another conversation we were told that recent experience with building projects has shown that the estimated cost per m2 is approximately NOK 29 000, - ex VAT, but including the cost of buying the building site. Melhus Municipality have recently completed the construction of a new nursing home. The price per m2 was about NOK 25,000, -. When compared to purchasing housing units on the open market, a municipal project project is much cheaper per m2.

However when planning the development of new dwellings the municipality focuses standard Norwegian housing sizes. The need for housing for large families is the exception. If the need arises for a larger home, the municipality looks for suitable housing on the open market.

The Municipality employs a “rent before ownership” concept. Where disadvantaged residents rent first and can aim for future ownership of their home. This is not successful in all cases. Some of the houses that refugees are renting are large new low-energy houses, located close to the town centre. Residents will have difficulty affording such a house *“They get a start loan if both have a job. But with low paid jobs, they cannot afford the housing prices in the town centre.”* In these cases, they have to find another dwelling that they can afford to buy or continue to rent.

Earlier in the text, housing guidance is mentioned and both representatives stated that this was an important part of what “Welcome to Melhus” includes. This guidance has an impact on the cost associated with refugee settlement and the maintenance of the dwellings. We mentioned to the two representatives that we were surprised about the level of energy awareness and low indoor temperatures found among the six interviewees. We were also, we said, impressed by how they talked about the looking after the homes. According to the representatives, this is not something that happens by itself. It is a result of the housing guidance, and the hard economic facts related to the cost of living in Norway:

> *"Some of them have it hotter at home before they start working and have to start paying themselves. They turn the heat down when they get a job, and some taped over vents. That's why we focus on housing guidance."*

The Welcome to Melhus standard, by providing good housing, a feeling of welcome and support when solving the challenges of understanding how a home functions in Norway, works towards integration within the community and according to refugee informants, the standard works. The housing market is a challenge; the municipality struggles to find enough appropriate housing. Everyone one naturally wants a good standard and to live close to the centre of Melhus, but this means housing prices are high. The municipality encourages a rent before ownership practice, but this is often unsuccessful because the intention to provide good quality housing means refugees are often being provided with new houses that have a low energy standard that would be expensive on the open market. One solution would seem to be the municipality developing its own building stock of low-energy housing for rent and eventual future ownership.

**Energy use and solutions**

The projects original hypothesis was that it would be difficult to get a high level of ambition in terms of energy efficient housing because keeping to a low-cost level was important for the municipality. The 1, 2, 3! Boliger project has therefore proposed energy and cost-efficient solutions for future housing projects and we suggested to the municipal representatives that implementing more energy efficient solutions would provide cheaper housing solutions for the refugees. In the case of plus energy houses, the municipality could even harvest the surplus energy for other purposes, e.g. adjacent municipal buildings such as kindergarten or schools. The two municipal representatives had mixed feelings about energy efficient solutions and used plus-houses as an example,

*"Plus-houses are interesting. Melhus Municipality is a homeowner and if we had plus-houses, residents would have cheap energy for three years (they receive support for three years)."*

The reduction of energy costs was the positive side to having plus-houses in Melhus, an economic gain. There are they suggest also negative consequences

*"What happens after the three years are over? What kind of housing and energy use competency have the refugees achieved? And, is it fair that people go from refugee reception to living in plus-houses? We should not think about the environment, but some (ethnic Norwegians) will think it is unfair if "someone" gets a plus-house."*

According to Søholt et al. (2018) few of the municipalities that they contacted believed that the housing that was offered to refugees was better than the housing that was offered to other disadvantaged groups. It would seem that municipalities are aware of how their work with refugees will be looked upon by the wider community. The aim that all disadvantaged groups should receive appropriate housing is central to this work. On the other hand, the representatives from Melhus municipality told us that there are refugees who do not manage to move out of municipal housing and establish themselves without support within the community. Then plus-houses would be profitable for the Municipality since this would reduce the municipal costs associated with continuing to support these individuals within the community. The electricity bills are often paid by NAV.

If an energy efficient concept is implemented is it also important that the energy harvested can be used by the community: *"Plus-houses that sell electricity to another building should be houses owned by the Municipality"*. Selling these houses as part of a rent before ownership program would perhaps not be a good solution.

The pros and cons about energy efficient solutions have not stopped the Municipality in investing in heat pumps. When building public buildings such as schools, nursing homes, kindergartens the municipality often installs heat pumps based on groundwater. So far, among the refugees settled in the community, 15 homes have received heat pumps. This according to the representatives has meant warmer houses and electricity savings.

> *"It is impossible to say how much more Melhus Municipality is willing to pay for a better technical standard. The energy consumption of our properties is currently low, in addition to the fact that the electricity price seems set to remain low."*

### Summary and reflections

The findings show that the refugees we interviewed were in general content with their housing situation. They feel save and thrive in Melhus municipality. They appeared to cope well with what was unusual or new to them due to a different cultural background. The municipality provides them with the necessary information about their dwellings and provides help with new challenges that arise. The six refugee informants had different backgrounds and needs; the housing that the municipality had provided was therefore also different. Despite the variety, there are some common experiences and preferences. 1) The overall attitude to the dwelling and the particular solutions was also positive. 2) The kitchen was a room where informants were able to provide a more detailed description and this points to it being an important room in the house. 3) otherwise technical terms are difficult to understand and/ or explain. This we suggest could challenge the ability of refugees to state their preferences.

Before conducting the interviews, we had heard and read about difficulties people from other cultures had when adapting to Norwegian dwellings (not only refugees). It is sometimes suggested that newcomers close or tape over all potential sources of draughts, this can cause condensation, and in the long run would damage the building (Hauge et al. 2015). In addition, newcomers it is suggested, prefer higher temperatures than is common among "native" Norwegians, or that they use inappropriate cleaning techniques.

This may be true in some cases and if this happens, it represents challenges for municipalities, regarding building maintenance and expenses. However, during the interviews we saw no sign of these myths being realities. Interviewees mentioned challenges about the use of Norwegian dwellings, but the feedback also challenges the aforementioned myths:

1. The material use is different in Norwegian houses. They therefore require cleaning/ washing in ways that are different to what is common in the informants' home country. One informant mentioned that in the stone buildings from his home country, floors are washed with a lot of water. This technique would damage a Norwegian wood floor.

Why good practice can counteract myths: The settlement office in Melhus Municipality works actively with each refugee/family. They spend time explaining how the dwellings should be used/ maintained. They have a caretaker team that follows-up the dwellings and works on a social level helping the refugees with practical problems. They have a handbook that includes an explanation of rental contracts and building maintenance. The informant who initially used a lot of water to wash his house soon learned, with help from the Municipality, that this method was not functional in Norway where the primary building material is wood (and he laughed about his misunderstanding). Good settlement routines and practices helps to avoid the establishment of practices that can cause damage and lead to maintenance expenses.

2. Interviewees were all worried about the price of electricity in Norway. They all saw this as important living expense and they therefore tried to keep the temperatures in their homes at a relatively low level. Only one family mentioned having a temperature as high as 23 degrees and one male interviewee kept the temperature as low as 18 degrees. The majority stated that they aimed for 21 degrees. This is relatively low compared to what is found otherwise within the Norwegian context (Thomsen et al. 2017).

The interviewees did not often pay the electricity bill themselves. They are often paid by the Labour and Welfare management office (NAV)[3]. Despite this, informants aimed to keep their bills as low as possible. Interviewees all had limited financial resources. Although the general trend is for them to find some kind of employment after their settlement period is over (Gran 2014), their jobs are often unskilled and on the lower end of the pay scale. Developing housing that has low running costs would seem to be an important factor for the settlement and integration of refugees. It is also factor in general for the socially disadvantaged in the housing market.

The next section looks at energy ambitions and associated investment cost, and therefore provides potential solutions for what the interviews established as an important factor for refugee settlement.

[3] NAV – in Norwegian arbeids og velferdsforvaltning.

# 3. Energy ambitions

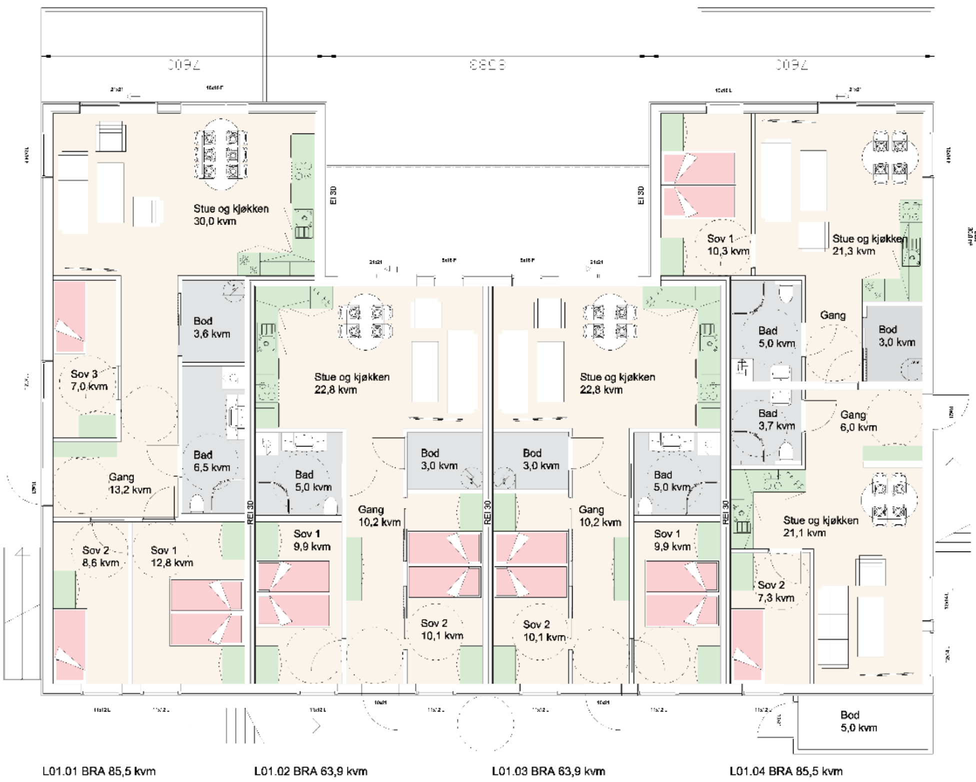
## Objective

The energy and cost analyses of the different energy efficiency solutions simulated in the residential building in Melhus aim at evaluating which of the chosen solutions gives the lowest energy use and the best balance between investment costs and payback from energy savings.

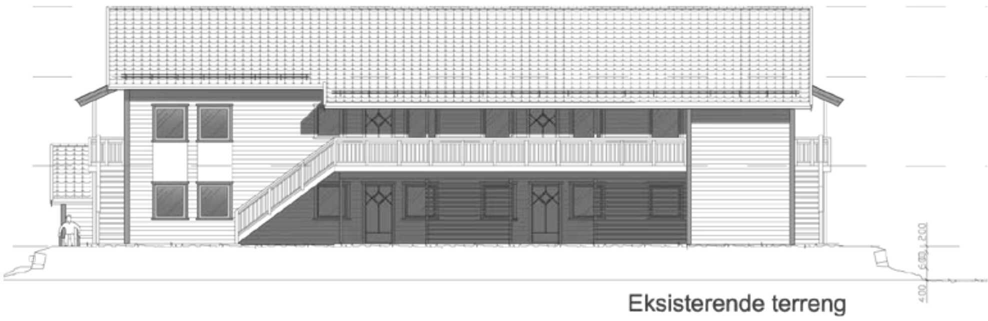
## Method

### Building description

The building modelled in the energy simulation consists of a 2-floor apartment building, with four apartments on each floor. The building, located in Strandveien 31, Melhus, has a total heated floor area (BRA in Norway) of 597 m$^2$ (298.5 m$^2$ in each floor). The building is detached, and the four facades are fully exposed. On each floor, two 85.5-m$^2$-apartments are on the North and South ends of the building, and two 63.5-m$^2$-apartments are in the centre of the building, thus their external walls are exposed towards East and West only (Figure 1 and Figure 2). Balconies are placed on the West façade, and a gallery that gives access to the first floor is on the East façade. The building, which is still in its planning phase, will be built according to the Norwegian TEK 17 building code. Thus, the energy efficiency performance of the building envelope is set to the energy measure method defined in the TEK 17, as shown in Table 3. The details of the building materials and layer thickness of the constructions of the ground floor, external wall, internal wall and floor, and roof are in Table 4.




*Picture 7: plan of the residential building in Melhus.*

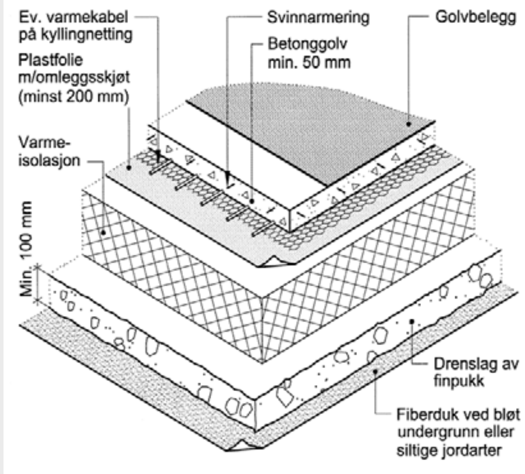
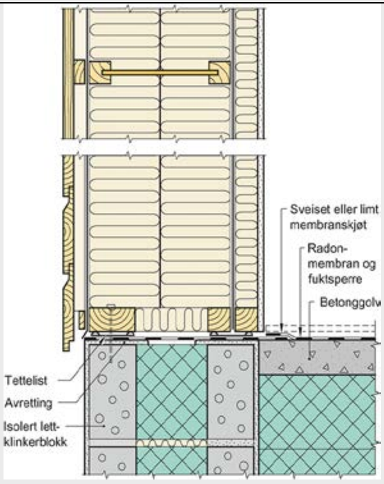
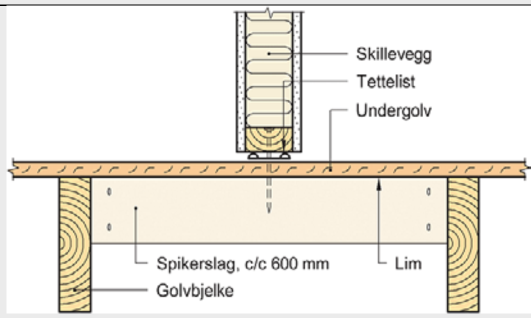
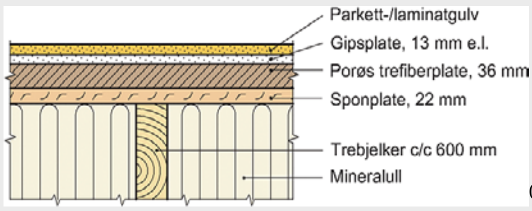



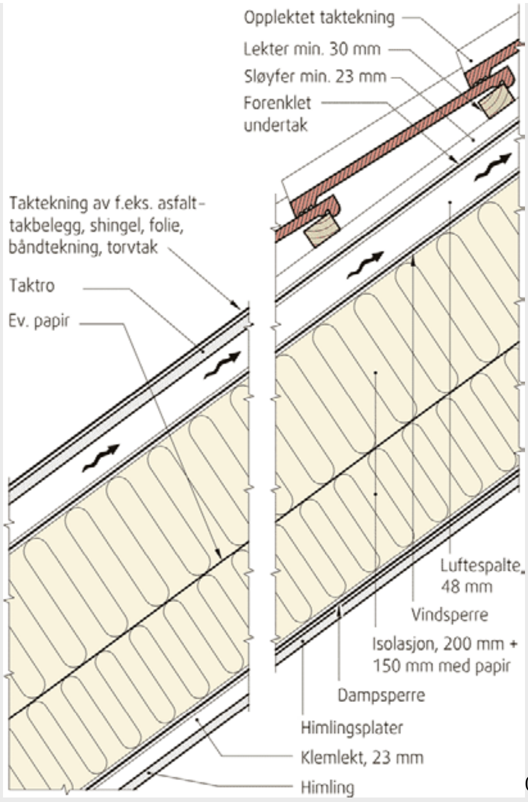

*Picture 8: South and East facades of the residential building in Melhus*

*Table 3. Characteristics of the residential building in Melhus.*

| | |
|---|---|
| Ground floor U-value | 0.10 W/m²K |
| External wall U-value | 0.17 W/m²K |
| Internal floor U-value | 0.15 W/m²K |
| Internal wall U-value | 0.23 W/m²K |
| Roof U-value | 0.13 W/m²K |
| Windows U-value (incl. frame) | 0.70 W/m²K |
| Windows g-value | 0.42 |
| Air tightness | 0.6 ACH |
| Normalized thermal bridges | 0.07 W/m²K |
| Mech. Vent. supply | 0.47 l/s m² |
| Opening fraction of windows | 0.10 |
| Mech. Vent. return | 0.47 l/s m² |
| Installed power for lights | 1.95 W/m² |
| Installed power for appliances | 3.00 W/m² |
| Installed power for DHW | 5.10 W/m² |
| Air-to-water heat pump SCOP| | 2.3 |
| Energy heat recovery efficiency | 80% |

*Table 4. Details of the construction systems used in the residential building in Melhus*

| Construction | Layer | Thickness [mm] | Technical drawing |
|---|---|---|---|
| Ground floor | wood flooring | |  (1) |
| | light insulation/noise dampening | 20 | |
| | concrete slab | 200 | |
| | barrier | | |
| | XPS insulation | 310 | |
| | barrier | | |
| External wall | gypsum board | 10 |  (2) |
| | timber frame | I-profile 48 x 200 | |
| | light insulation | 200 | |
| | wood cladding | | |
| External wall - ring wall | barrier | | |
| | concrete wall | 60 | |
| | XPS insulation | 80 | |
| | Concrete wall | 60 | |
| | barrier | | |
| Internal walls | gypsum board | 10 |  (3) |
| | timber frame | 48 x 100 | |
| | light insulation | 100 | |
| | gypsum board | 10 | |
| Internal floors | wood flooring | |  (4) |
| | gypsum board | 13 | |
| | wood fibre board | 36 + 22 | |
| | light insulation | 200 | |
| | wood load bearing structure | 70 x 200 | |
| | gypsum board | 10 | |
| Roof | ceramic tiles | | |
| | wood supporting structure | 30x48 | |
| | barrier | | |
| | barrier | | |

| | | | |
|---|---|---|---|
| | light insulation | 250 |   (5) |
| | wood load bearing structure | I-profile 48x250 | |
| | gypsum board | 10 | |
| (1) Byggforskserie 522.111 Fig. 25a<br>(2) Byggforskserie 523.251 Fig. 61b<br>(3) Byggforskserie 524.213 Fig. 74b<br>(4) Byggforskerie 522.511 Fig. 61<br>(5) Byggforskserie 525.101 Fig. 1ab | | | |

**Building user profiles**

Since the scope of the analysis is to evaluate to what extent different energy efficient solutions reduce the yearly building energy use and relative energy cost, specific profiles of the future building occupants were used in the energy simulations instead of the standard occupancy profiles, which are defined in the NS 3031:2014. The user profiles consist of different setpoints for heating, and time schedules for the building occupancy, the use of artificial lights, equipment, and domestic hot water, and the opening of window for natural ventilation. The profiles were developed according to the expected occupancy and behaviour of the building's future occupants, which are derived from the household unit, the number of occupants, the number of hours usually spent at home, and the indoor temperature preferences. The information was extracted from the interviews described in Table 2. Based on these variables six different users are modelled, to which the heating set-points and the schedules for occupancy, lights, appliance, Domestic Hot Water (DHW), and natural ventilation are attributed, as described in Table 5. The natural ventilation schedule was introduced in the energy model to simulate the expected opening and closing of windows throughout the day. It is worth noticing that the building is mechanically ventilated, thus the ventilation requirement is met, regardless of the natural ventilation. It is expected that the users will partially open windows for 1 hour at different time of the day, as shown in Table 5. An air-to-water heat pump with a SCOP of 2.3 meets the yearly building energy demand, for space heating.

*Table 5. Daily schedules of heating, occupancy, use of lights, appliances, DHW, and windows.*

| | | | |
|---|---|---|---|
| Heating setpoint | 06:00-22:00 | 21 °C | User 1, 2, 5 |
| | 22:00-06:00 | 19 °C | |
| | 06:00-22:00 | 23 °C | User 3 |
| | 22:00-06:00 | 22 °C | |
| | 06:00-22:00 | 21 °C | User 4 |
| | 22:00-06:00 | 21 °C | |
| | 06:00-22:00 | 20 °C | User 6 |
| | 22:00-06:00 | 18 °C | |

| | | | |
|---|---|---|---|
| User occupancy | 00:00-08:00, 17:00-24:00 | weekdays | User 1, 4 |
| | 00:00-24:00 | weekends | |
| | 00:00-24:00 | everyday | User 2, 3, 5 |
| | 00:00-08:00, 17:00-24:00 | weekdays | |
| | 00:00-24:00 | weekends | |
| | 00:00-08:00, 13:00-24:00 | weekdays | User 6 |
| | 00:00-24:00 | weekends | |

| | | | |
|---|---|---|---|
| Light schedule | 06:00-08:00, 17:00-23:00 | everyday | User 1, 4, 6 |
| | 06:00-22:00 | everyday | User 2, 3, 5 |

| | | | |
|---|---|---|---|
| appliances schedule | 06:00-08:00, 17:00-23:00 | everyday | User 1, 4, 6 |
| | 06:00-22:00 | everyday | User 2, 3, 5 |

| | | | |
|---|---|---|---|
| DHW schedule | 06:00-08:00, 17:00-23:00 | everyday | User 1, 4, 6 |
| | 06:00-22:00 | everyday | User 2, 3, 5 |

| | | | |
|---|---|---|---|
| Windows opening schedule | 07:00-08:00, 11:30-12:30, 18:00-19:00 | everyday | User 2, 3, 5, 6 |
| | 07:00-08:00, 18:00-19:00 | workdays | User 1, 4 |
| | 07:00-08:00, 11:30-12:30, 18:00-19:00 | weekends | |

**Energy efficiency solutions and energy simulations**

Different energy saving solutions were simulated in a building energy model and energy simulations were run by implementing each solution. This approach ensured a better evaluation of the solutions that yield the highest energy savings. From the best performing solution, a sensitivity analysis was run to evaluate the efficacy of on-site energy production technology with respect to annual energy balance and cost payback time. The energy saving solutions were chosen among those that are typically employed in residential buildings, as described in Table 6. The energy simulations were performed using IDA ICE v.4.7 which allows a dynamic analysis of the thermal exchanges between the building and the outdoor environment. The analysis was performed by using a Typical Meteorological Year in Trondheim, which was obtained from the closest weather station available (Trondheim Værnes).

The sensitivity analysis consisted in simulating different orientations of roof-mounted photovoltaic panels, solar thermal panels, and combinations of solar panels and a ground-source heat pump (SCOP 3.3). The overall efficiency of the photovoltaic system is 16%, which is given by a combination of a 20%-efficiency of the panels and a 0.8-performance-ratio given by system losses (such as those due to the inverter, temperature, and cables). The solar panels have an efficiency of 75%. The area covered by the photovoltaic is 145 $m^2$ on the East roof and 50 $m^2$ on the South roof. The solar thermal panels are installed on the East roof only and cover an area of 100 $m^2$. The difference of installed area of PV is due to the roof shape, the largest usable surface is the East-oriented. The West oriented roof surface is not considered for the solar-energy installations due to the shading given by the two West-facing wings of the building. The South-facing roof is not considered for the installation of the solar thermal panels given the small available area with this orientation. The solar thermal panels are connected to the air-to-water heat pump via a water tank in *Variation d*, and to the ground-source heat pump in *Variation f*, thus reducing the energy need for the water-based space heating.

*Table 6. Description of the energy efficiency solutions.*

| | |
|---|---|
| 1st round of simulations | |
| Baseline | Building solution used as benchmark, description of energy efficiency solutions applied is to find in Table 3and Table 4 |
| Variation 1 | Baseline solution + increased energy recovery in balanced ventilation (efficiency 0.85) |
| Variation 2 | Variation 1 + increased air tightness (from 0.6 to 0.3 ACH) |
| Variation 3 | Variation 1 + lower U-value of ground floor (0.08 $W/m^2K$), external wall (0.11 $W/m^2K$), and roof (0.11 $W/m^2K$) |
| Variation 4 | Variation 1 + Variation 2 + Variation 3 |
| 2nd round of simulations | |
| Variation 1a | Variation 1 + photovoltaic panels installed on the East-facing slope of the roof |
| Variation 1b | Variation 1 + photovoltaic panels installed on the South-facing slope of the roof |
| Variation 1c | Variation 1 + photovoltaic panels installed on both the East- and South-facing slope of the roof |
| Variation 1d | Variation 1 + solar thermal panels installed on the East-facing slope of the roof |
| Variation 1e | Variation 1 + ground source heat pump |
| Variation 1f | Variation 1d + Variation 1e |

**Cost data and analysis**

The cost analysis is performed on the Baseline, Variation 1, and all the variations in the 2nd round of simulations (as shown in Table 7). This is because the Variations 2, 3, and 4 do not add significant energy savings to the results obtained in Variation 1. The calculation of the energy cost is based on the electricity use for the HVAC, space heating (provided by the heat pump), the on-site electricity production (photovoltaic), and the on-site heat production (solar thermal). The electricity use for equipment and lighting is excluded from the cost calculation as their energy is not influenced by the different energy saving solutions. The heat production is supposed to reduce the electricity needed for an electric boiler for domestic hot water, and, therefore, the heat generated is considered as electricity-sourced, with respect to the cost calculation. The cost for the building construction is not included in the calculation, as this is assumed the same in all the variations. The replacement of the installations (heat pumps, photovoltaic panels, heat recovery, etc) is included in the cost calculation, and a 0.4%-yearly-degradation rate of the PV production is also considered. With regard to the PV panels, these will yield a higher efficiency when replaced in 25 years, which is expected to double the overall efficiency of the system (currently 16%) due to the advance of technological development in this field. An annual 3% discount rate of the NOK currency is included in the cost analysis, and a 2.3% annual increase of the electricity cost is considered for the purchased and the produced electricity. The predicted increase of electricity cost in Norway is sourced from the latest NVE report (NVE 2017). Since electricity is assumed as the only energy used in the building for all the end uses, the electricity cost calculated for year = 1 is sourced from the Statistics Norway, and it is set to the value given for the last quarterly period in 2017. This corresponds to 0.96 NOK/kWh and includes the cost for the electricity use and the grid use. The investment cost from the different technologies and their replacement rate are shown in Table 7. The investment cost of the air heat recovery is calculated according to estimates proposed by Direktoratet for Byggkvalitet (DiBK 2018), which gives an average of 450 NOK/$m^2$ of floor heated area, and the expected service life is estimated from producers of such systems. The investment cost of the air-to-water heat pump is sourced from the 2015 NVE report (NVE 2015) and it consists of equipment cost (6 500 NOK/$kW_{produced\ heat}$) plus installation cost (200 NOK/$kW_{produced\ heat}$). The same report is used as source for the investment cost of the ground-to-water heat pump, the PV system, and the solar thermal panels. The investment cost of the ground-to-water heat pump consists of approximately 16 000 NOK/$kW_{produced\ heat}$ for the equipment plus 500 NOK/$kW_{produced\ heat}$ for the installation. The investment cost of photovoltaic systems is 26 000 NOK/$kW_p$, which consists of 9 000 NOK/$kW_p$ for the PV modules, 7 000 NOK/$kW_p$ for the ancillary equipment (inverters, cables, frames, etc), and 10 000 NOK/$kW_p$ for the installation. The replacement of the ancillary equipment (every 12 years) is assumed to claim for half of the initial investment cost. The investment cost of the solar thermal panels consists of the costs for the solar modules, water pipes, the management system, the water tank, and the installation. It is assumed that 16% of the total investment cost is needed for the replacement of the management system every 12 years, while the rest of the components are replaced every 25 years.

*Table 7. Investment costs of different energy efficiency solutions.*

| Installation | Investment cost (NOK) | Service life (years) | Variations installed |
|---|---|---|---|
| Air-to-water heat pump | 268 000 | 15 | Baseline, Variations 1-4, Variations 1a-1d |
| Ground-to-water heat pump | 641 600 | 20 | Variations 1e, f |
| Air heat recovery | 269 000 | 20 | All |
| Photovoltaic panels | 450 000 | 25 | Variation 1a |
| Photovoltaic panels | 185 000 | 25 | Variation 1b |
| Photovoltaic panels | 635 000 | 25 | Variation 1c |
| Solar thermal panels | 366 800 | 25 | Variation 1d, f |

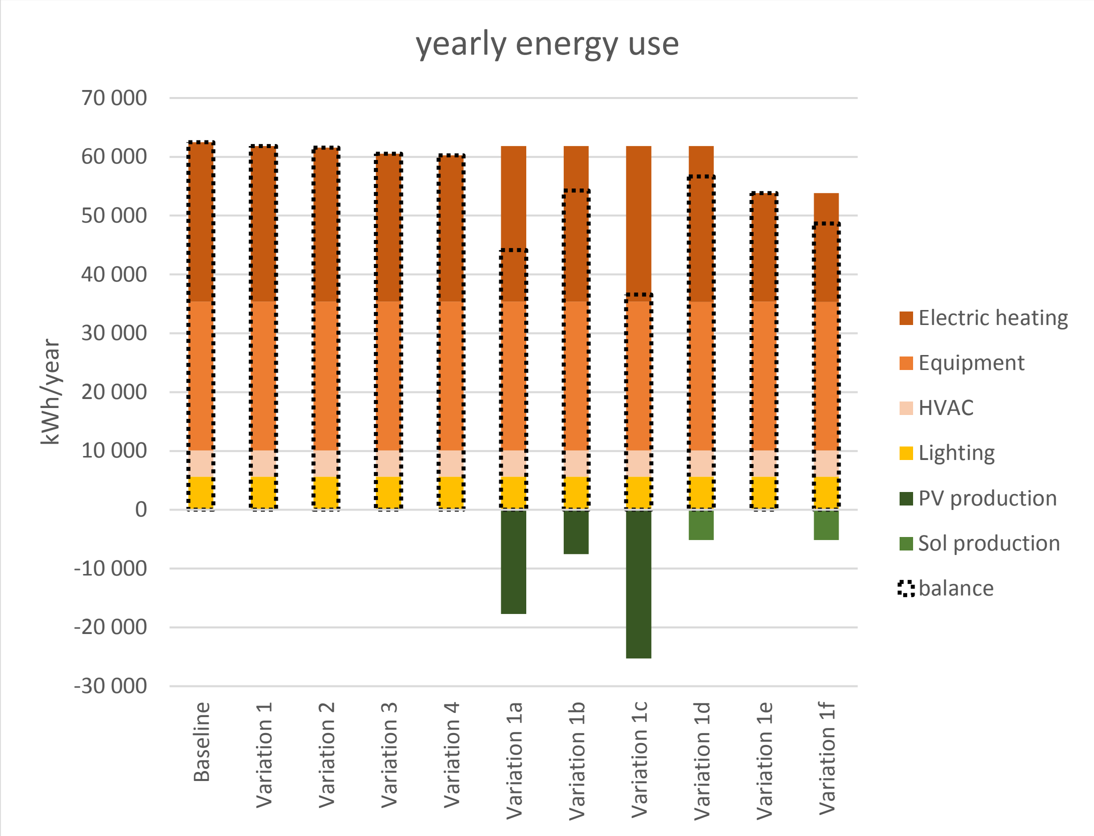
## Results

### Energy analysis

Picture 9 shows the results of the yearly energy use of the baseline and the variations in the energy efficiency solutions. The baseline has an annual energy use of 62 493 kWh, which equals to 105 kWh/$m^2$ year, and the annual energy use of Variations 1-4 is between 104 kWh/$m^2$ year and 101 kWh/$m^2$ year. Both the baseline and the above variations do not meet the TEK 17 requirements for annual energy use (which is set to 95 kWh/$m^2$ year), due to the additional energy losses given by the window opening schedule, which is not in compliance with the NS 3031:2014 energy calculation method. When comparing the Baseline with Variation 1, the installation of an air heat recovery with a higher efficiency (from 80% in the baseline to 85% in Variation 1) has a small effect on reducing the building electricity use (from 105 to 104 kWh/$m^2$ year), due to the negative effect of the window opening schedule. Similarly, the installation of the other energy efficiency solutions (Variations 2-4) has a limited effect on reducing the building electricity use, as the expected energy savings are 1.5 kWh/$m^2$ year, 3 kWh/$m^2$ year, and 3.5 kWh/$m^2$ year for Variation 2, Variation 3, and Variation 4, respectively. It is worth remembering that a natural ventilation strategy is simulated in all the solutions, which causes a considerable amount of heat to be lost via ventilation and, therefore, limits the potential of energy savings given by better air tightness and increased insulation of the building envelope. Therefore, the highest achievable annual energy saving which is obtained by installing a more efficient heat recovery unit, increase the air-tightness and the insulation level of the building (as detailed in Table 6) is less than 4%.

Given this these results, it was then decided to use the Variation 1 as the starting point for estimating the potential of further energy saving by means of on-site renewable energy production or different heat pumps. Variations 1a-c in Picture 9 show the potential of electricity production from PV installed on the roof of the building (in dark green) and the overall balance (energy use – energy generated) in dotted line. The installation of 145 $m^2$ of PV on the East-facing roof produces 17 708 kWh/year (Variation 1a), according to the simulation. This gives an overall energy balance of 44 139 kWh/year which equals to 74 kWh/$m^2$ year. The 50-$m^2$-area of PV on the South roof produces 7 564 kWh/year and gives an energy balance of 91 kWh/$m^2$ year, and the combination of the two above produces 25 272 kWh/year for an energy balance of 61 kWh/$m^2$ year.

Despite the South-facing-PV-area being just 34% of the East-facing area, the yearly electricity production of the former is 42% of the latter, due to the better orientation and higher solar radiation. The installation of the solar thermal panel (100 $m^2$ on the East roof), as shown in Variation 1d, produces 5 161 kWh of thermal energy and gives a yearly balance of 95 kWh/$m^2$ year. By substituting the air-to-water heat pump with a ground-source heat pump (bore-holes and water-based heating system), the energy for space heating decreases from 44 kWh/$m^2$ year to 31 kWh/$m^2$ year, due to the higher SCOP (Seasonal Coefficient Of Performance) of this system. The ground-source heat pump gives then a 34% energy saving with respect to the air-to-water heat pump, but this represents just 14% of the total energy use of the building. By adding the solar thermal panel to the ground source heat pump (Variation 1f), the yearly balance of the building energy use decreases from 90 kWh/$m^2$ year to 81 kWh/$m^2$ year. With respect to the heating system and the on-site renewable system, the ground source heat pump and the PVs give the best performance. However, the combination of these two has not been simulated because the additional savings on the space heating given by the ground source heat pump are marginal with respect to the total energy use of the building, and by large extent lower than those achievable by installing PVs only. In such a perspective, the high cost of installation for ground source heat pumps does not seem to justify the low cost-saving.

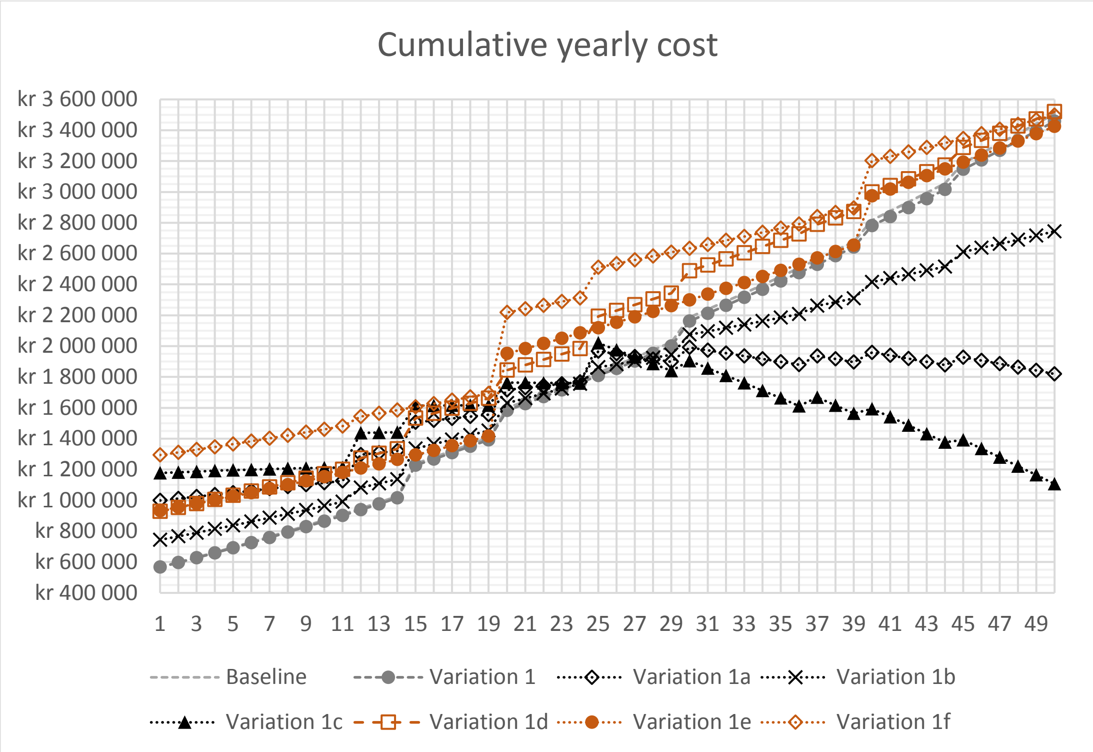



*Picture 9. Yearly energy use of the different energy-efficient solutions.*

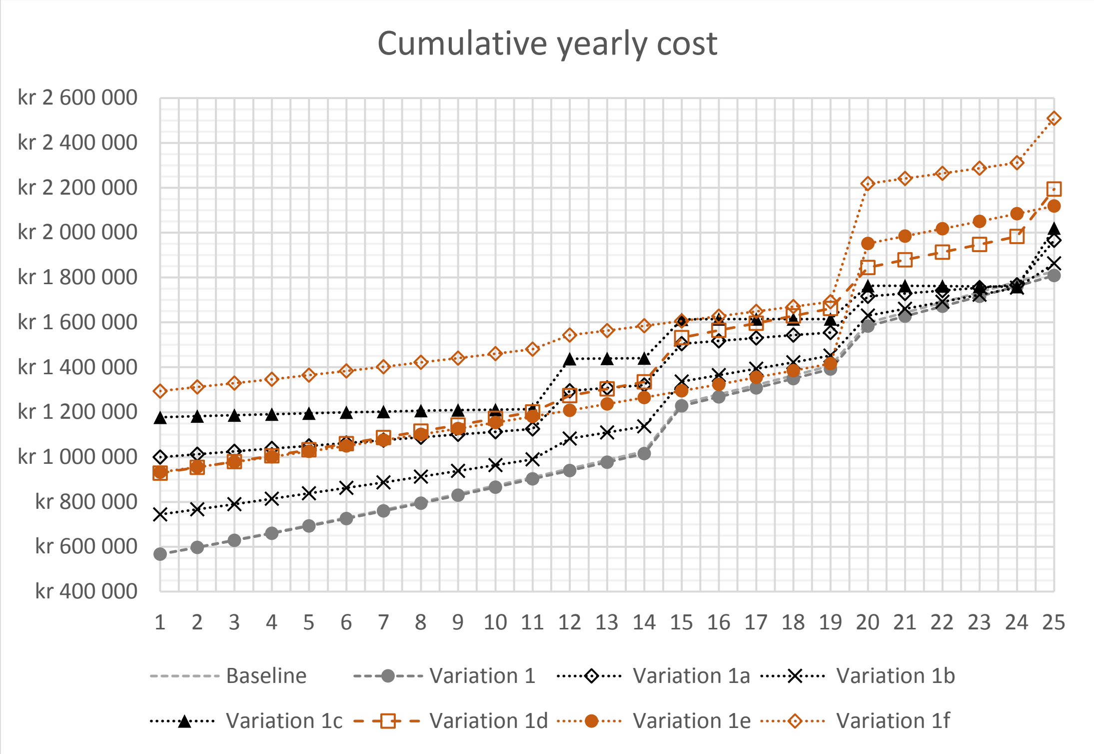
**Cost analysis**
Pictures 10 and 11 shows the cumulative life cycle cost of the Baseline and the Variations 1 and 1a to 1f. Picture 11 shows the results limited to the first 25 years of the lifecycle cost analysis. The cost analysis is based on the yearly electricity cost for the energy use for space heating, HVAC use, and on-site production (thermal solar and PV), shown in Picture 9. The Baseline and Variation 1 have the lowest initial investment (536 650 NOK), followed by Variation 1b (721 650 NOK), Variation 1d (903 425 NOK), 1e (910 250 NOK), 1a (986 650 NOK), Variation 1c (1 171 650 NOK), and Variation 1f (1 277 025 NOK). The Baseline and Variation 1 have the same initial investment cost as the cost of the 80%-efficiency and the 85%-efficiency heat recover are assumed the same. The figure shows the payback time in years needed to balance the additional investment cost implemented in all the variations, with respect to the Baseline. The payback is assumed at the first crossing of the corresponding lines in the chart. The jumps in the lines correspond to the investment cost given for replacing the energy system and ventilation components. It is worth remembering that in the cost calculation the investment cost is discounted by a 3% interest rate, the electricity price (for both purchased and produced electricity) increases by 2.3% per year, the efficiency of the PV systems (in Variation 1a,b,c) decreases by 0.4% per year. The Baseline and Variation 1 have almost overlapping curves, thus meaning the increased efficiency of the heat recovery does not produce noticeable cost savings.

Variation 1a,b, c starts from different initial investment costs (the initial investment cost of Variation 1c is 1.6 times that of Variation 1b) but all three converge after 24 years, after which Variation 1c shows substantial cost savings. After 28 year all the solutions with PVs have a cumulative cost which is lower than that of the Baseline. It is worth remembering that the PV system is replaced after 25 years, and the expected new efficiency is two times that of the PV installed in 2017. For this reason, the annual cost balance of Variation 1c becomes negative after 26 years, and after 41 years for Variation 1a, thus meaning the electricity produced by the PV system is more than the building electricity use for heating and HVAC. However, the Baseline curve is steeper than the curve of Variation 1a,b,c even before the replacement of the PV system (at year = 25), and this means that after 24 years these three solutions show a better cost performance than that of the Baseline, regardless of the increased efficiency of the new PV system. It is worth noting that Variation 1c pays off its cumulated investment and energy cost after 43 years, when the yearly cumulative cost is lower than the initial investment cost.

Variations 1 d , e, f perform better than the Baseline after only 47 years, due to the high investment cost of the ground source heat pump (Variation 1e and 1f) and the low energy production from the solar thermal panels (Variation 1d and 1f).




*Picture 10. Investment cost and running cost (50-years-time horizon) of the different energy-efficient solutions.*




*Picture 11. Investment cost and running cost (25-years-time horizon) of the different energy-efficient solutions.*

*Table 8. Energy cost and investment cost of the different energy saving solutions.*

| 25 years | | | | | |
|---|---|---|---|---|---|
| | Energy cost (heating + HVAC - PV - Solar thermal) | total investment cost | Sum | Profitability | Total cost $variation_x$/total $cost_{baseline}$ |
| Baseline | kr 971 083 | kr 857 414 | kr 1 828 497 | | 100.0 |
| Variation 1 | kr 951 240 | kr 857 414 | kr 1 808 654 | 0.00 | 98.9 |
| Variation 1a | kr 285 792 | kr 1 680 147 | kr 1 965 939 | 1.20 | 107.5 |
| Variation 1b | kr 666 987 | kr 1 195 649 | kr 1 862 636 | 1.11 | 101.9 |
| Variation 1c | kr 1 539 | kr 2 018 382 | kr 2 019 921 | 1.20 | 110.5 |
| Variation 1d | kr 757 773 | kr 1 437 450 | kr 2 195 223 | 2.72 | 120.0 |
| Variation 1e | kr 704 507 | kr 1 414 233 | kr 2 118 740 | 2.09 | 115.9 |
| Variation 1f | kr 511 039 | kr 1 999 405 | kr 2 510 444 | 2.48 | 137.3 |
| 50 years | | | | | |
| | Energy cost (heating + HVAC - PV - Solar thermal) | total investment cost | Sum | Profitability | Total cost $variation_x$/total $cost_{baseline}$ |
| Baseline | kr 2 385 871 | kr 1 121 052 | kr 3 506 924 | | 100.0 |
| Variation 1 | kr 2 337 121 | kr 1 121 052 | kr 3 458 173 | 0.00 | 98.6 |
| Variation 1a | -kr 198 883 | kr 2 019 157 | kr 1 820 274 | 0.35 | 51.9 |
| Variation 1b | kr 1 253 839 | kr 1 490 273 | kr 2 744 112 | 0.33 | 78.2 |
| Variation 1c | -kr 1 282 164 | kr 2 388 377 | kr 1 106 213 | 0.35 | 31.5 |
| Variation 1d | kr 1 805 189 | kr 1 716 321 | kr 3 521 510 | 1.03 | 100.4 |
| Variation 1e | kr 1 730 916 | kr 1 693 277 | kr 3 424 193 | 0.87 | 97.6 |

| | | | | | |
|---|---|---|---|---|---|
| Variation 1f | kr 1 198 984 | kr 2 299 091 | kr 3 498 075 | 0.99 | 99.7 |

Table 8 shows the energy cost, the total investment cost, and the ratio between the difference of investment costs and the difference of energy costs found in all the variations with the Baseline. The ratio of costs between the energy saving solutions is calculated as follows:

$$\frac{(Investment\ cost_{Variation\ x} - Investment\ cost_{Baseline})}{(Energy\ cost_{Baseline} - Energy\ cost_{Variation\ x})}$$

The values in this column in the table above are, therefore, meant to give an overview of the profitability of every NOK invested in additional energy saving solutions against the cost saving given by the same solution. In such a perspective, the lower the number, the higher the profitability, which is translated in a small difference of investment cost and a substantial difference of energy cost. As shown in the table, the results show what is seen in In the 25-years scenario, all the proposed energy saving solutions give a profitability-ratio higher than 1. This means that the Baseline gives the lowest total cost in a 25-year-time horizon. The profitability of Variation 1 is equal to that of the Baseline, given the very similar yearly cost balance. Variations 1b gives a profitability ratio of 1.11, which means that after 25 years performs almost as good as the Baseline.  The other two solutions with PV panels have similar profitability ratios (1.2), and the remaining solutions are all above 2.0.

In the 50-years scenario, most of the proposed solutions gives a higher profitability than the Baseline, with the exception of Variations 1d (solar thermal panels, 1.03). Variation 1f (solar thermal panels + ground source heat pump) is almost equal to the Baseline (0.99). Variation 1b gives the highest profitability ratio (0.33), followed by Variation 1c and 1a (0.35), thus meaning that in terms of energy saved against additional investment cost, the solutions with the smallest area of PV panels gives the most profitable solution. In conclusion, among the solutions with PV panels, Variation 1b results as the most profitable (highest energy saving against lowest additional investment in comparison to the Baseline), but Variation 1c give the highest energy saving in absolute value.

By assuming the total cost (energy cost and investment cost) for the 50-years building lifetime, the Variations with the PV panels (Variations 1a, b, and c) has the lowest total cost, as shown in Table 8. Variation 1c gives a total cost equal to 31.5% of that of the Baseline, followed by Variation 1a (51.9%), and Variation 1b (78.2%). The solutions with either the solar thermal panels or the ground source heat pump, and the combination of the two give total cost higher than 97% of that of the Baseline.

### Energy: Summary and reflections

It is worth noting that all the solutions include the use of an air-heat recovery unit, which has quite a substantial initial investment cost. However, the potential energy saving is not fully exploited in the simulations as consistent energy losses via natural ventilation are assumed to simulate a possible real use of the building. If the installation of heat recovery is to be excluded from the solutions implemented in Variation 1a to Variation 1c, the lower initial investment cost and replacement cost may lead to a higher profitability and shorter payback times in these solutions. On the other hand, by assuming an ideal use of the building in which natural ventilation is excluded from the energy calculation, the yearly cost saving given by the installation of air-heat recovery would be much higher than that simulated. Similarly, the solutions that consider increasing the insulation level of the building envelope (Variation 2-4) would give lower yearly energy use, and a lower payback time than those solutions that consider the installation of PV or a ground-source heat pump. This is due to two main reasons. First, the simulated schedule for window opening leads to a large amount of thermal energy wasted via ventilation, thus reducing the effectiveness of improved envelope insulation. Second, the investment cost of increasing the insulation level of the building envelope is typically lower than that given by installing photovoltaics or a ground-source heat pump (NVE 2015).

As described in the method section, the variation in the electricity price is based on the NVE report of 2017 (NVE 2017), in which the prediction of future price is forecasted until 2030. In this study, the same annual increase of electricity price is expected after 2030, which is a harsh simplification in the calculation model. At the time of writing this report, the electricity price for residences (1.06 NOK/kWh, first quartal 2018) is higher than that used initially in the cost analysis (0.96 NOK/kWh, fourth quartal 2017). A higher than predicted future electricity cost will increase the profitability of the solutions that reduce considerably the yearly energy use (Variation 1a, c) with a high investment cost. The current yearly increase of electricity price is set to 2.3%. By assuming a yearly increase of 3.3% of electricity price, the total cost of Variation 1c decreases to 17.9% of the Baseline's total cost, whereas it was 31.5% with the 2.3% yearly increase. The total cost of Variation 1a decreases from 51.9% to 42.3% of the total cost of the Baseline. Therefore, by assuming an additional 1% of yearly increase of electricity price in the next 50 years, the solution with the highest PV area decreases its total cost by almost half, due to the additional profit given by selling the electricity excess at a higher price. On the contrary, the solutions with the solar thermal and the ground source heat pump (Variation 1f), decreases its total cost from 99.7% to 94.2% of the total cost of the Baseline.

The information regarding the investment cost of the different energy efficiency solutions refers to cost data issued in 2015. This may have led to an inaccurate cost analysis, given the 3-year difference between the NVE report and this publication.
In conclusion, by including the schedule of window opening in the building simulation, the results show that the installation of energy recovery gives the lowest cumulative energy and investment cost in a 25-year-horizon of building operation. By analysing a 50-year-horizon of building operation, the solutions that include the installation of PV gives lower cumulative energy and investment cost than the Baseline.

# 4. 1, 2, 3! Housing: Summary and conclusions

## Two parts that complement each other

The 1,2,3! Housing project is an interdisciplinary project, and although it consists of two parts that were different in focus and method, the two parts complement each other. Part one considers housing quality and part two analyses the energy ambitions associated with plans for a public housing project. The project started with a hypothesis that improving the energy effectiveness of housing for the socially disadvantaged would support housing quality. It was also proposed by the project team that providing cost effective energy efficient housing was possible when developing public housing. These two hypotheses have been confirmed during the process of gathering empirical data. We have followed up these hypotheses with a series of research questions:

## Housing quality

1. How do the refugees of Melhus reflect upon their Norwegian dwelling?
2. How do they describe cultural differences between the dwellings they were used to and the Norwegian dwelling?

Norwegian houses suit the Norwegian climate and the materials and layout that are found in houses in Melhus are typically Norwegian. The informants that we spoke to in Melhus came from cultural backgrounds where climate conditions require different kinds of housing to what is typical in Norway. The materials and layout are different. The refugees among our informant group had adapted to the difference and the difference between the housing from their original country and Norwegian houses was not something that they had reflected about a lot. The adapted and apparent satisfaction with their housing by our informants in Melhus is not something that is a given. The feeling of being at home, understanding how to maintain this home and qualities, are skills that have to be developed. These are challenges that are known within Norwegian housing research (Søholt et al. 2015, 2018, Hauge et al. 2017). Location, access to public transport, the size of their home and the housing standard are all factors that support the integration of refugees into the local community. Social quality is vital for integration, but the importance of physical qualities provided by the built environment should not be underestimated.

3. What are other aspects they are concerned with regarding their dwelling in Norway? (e.g. location, appliances, electricity costs, quality, indoor temperature, etc.)

So, what is different about Melhus municipality? Importantly Melhus provides an example of housing settlement policy that functions well on practical, structural and social levels. Melhus municipality has developed the "Welcome to Melhus standard", which offers a feeling of warmth and welcome that is spread thickly over the first confusing days within the community and is followed up by an interdisciplinary team within the municipality.
The Norwegian skills of our informants, varied but they all struggled to understand what we meant by housing preferences, even though we attempted to simplify our terminology. However, certain aspects did come across as important. They were interested in their kitchens, both men and women emphasised the importance of functionality. They had learned how to maintain their homes and this was built upon the help and information provided by the municipality when they first moved to the community. They were also interested in how much their electricity bills were and attempted to reduce their energy use. Average required temperatures were in general lower than what an ethnic Norwegian would require of his or her home. Their energy requirements are based on our informants being part of low-income households. They are supported by NAV, but were still interested in energy savings.

With regard to functionality 1,2,3! Housing's informants show a similar interest to ethnic Norwegians, whose housing preferences are also often based on what kind of kitchen is installed and on location. The interest shown by our informants in energy saving is different. The price of energy is currently low on the Norwegian market; there is therefore in general little focus on saving energy. Providing housing that is functional and enables residents to keep energy bills to a minimum would seem to be relevant within Melhus and housing concepts developed in Melhus are potentially transferable to other Norwegian municipalities. This suggests that a follow up project that considers energy use and knowledge about energy saving among socially disadvantaged in a wider Norwegian context would be useful. Other preferences with regard to housing quality indicate the situation in other municipalities will be similar, but more data on this theme would be useful.

## Energy analysis

The analysis of the energy use of the proposed residential project for refugees in Melhus consisted in comparing the yearly energy use and the cumulative cost for 50 years of building operation of 10 energy saving solutions. These were compared to the standard energy efficiency solutions implemented by the TEK 17 building code, which was used a reference scenario, and thus, named *Baseline*. The first four energy saving scenarios consisted of increased insulation level, lower infiltration rate, better efficiency of the air heat recovery unit, and a combination of the above (named Variation 1, 2, 3, and 4). The remaining six energy saving scenarios consisted of use of Photovoltaic panels on different roof orientations, solar thermal panels, ground source heat pump, and combinations of the above (named Variations 1a, b, c, d, e, f). These six scenarios were built on the settings given in Variation 1, which consisted of the basics TEK-17 requirements for energy efficiency plus an increased efficiency for the heat recovery unit (from 80% to 85%). The energy analysis was both based on the requirements set in the NS 3031 (with regards to the energy use for lighting, appliances, and HVAC use) and settings that were derived from the interviews on the occupants. Specifically, the preferred indoor temperatures were set according to those reported by the interviewees, and the occupancy schedules were set to reflect different family compositions and daily routines. The schedules were used for the window opening, artificial lighting use, appliances use, and domestic hot water use that were assumed realistic in the occupant's daily life.

The results of the energy analysis showed that the achievable energy savings given by implementing the energy efficiency solutions of first four scenarios (Variations 1, 2, 3, and 4) are less than 4%. Setting the yearly energy use of the Baseline equal to 100, the lowest energy use was given in Variation 4 (96.4). On the other hand, the implementation of the energy efficiency solutions of the last six scenarios gave between 9% and 41% of yearly energy reduction. Specifically, the lowest energy saving was obtained by the installation of the solar thermal panels (Variation 1d = 90.7), and the highest saving was given by the use of PV on both the East-facing and the South facing roof (Variation 1c = 58.5).

Given the promising results in terms of energy saving from the scenarios in Variations 1a-f, these were further investigated with respect to their cumulative cost. The cost calculation was based on the following considerations:

- the initial investment cost of the different technologies in addition to the Baseline (PV panels, solar thermal panels, and ground source heat pump),
- the investment cost of the more efficient heat recovery unit was not deemed higher than that of the basic heat recovery unit,
- the investment cost for the maintenance and replacement of the components of the above technologies for a building life span of 50 years,
- an annual increase of electricity price based on forecast found in literature,
- an annual depreciation of the NOK,
- an annual degradation rate of the efficiency of the PV panels,

- an annual increase of efficiency of the PV panel that leads to doubled efficiency in 25 years, when the new panels will be installed,
- a starting electricity price set at the last quarterly of 2017.

By setting the cumulative cost (energy plus investment for 50 years) of the Baseline equal to 100, the solution with the lowest total cost is given by Variation 1c (31.5), and the solution with the highest total cost is given by Variation 1d (100.4). The solutions with the PV panels give the first three lowest total cost, depending on the amount of PV installed and their orientation. The variation of the future electricity price was found to have a strong influence on reducing the total cost of those solutions with PV panels, as an increase of the future electricity price produces large profits from the selling of the excessive electricity production.

## Conclusion

The Norwegian State Housing Bank has made a positive contribution to the settlement of refugees in Melhus and in other Norwegian communities (Søholt et al. 2018). This contribution has been both financial and through the exchange of information. This work should continue and it is suggested here that focus and energy use during municipal housing development would be a further contribution. This could take the form of financial incentives to municipal housing projects that focus on reducing energy consumption and on the production of renewable energy. In addition, more information about the potential energy savings when developing energy efficient social housing would support the process. We also propose that refugees are provided with more information about how the Norwegian energy billing system works, for example the separation between grid rental and the price of kilowatt-hours is an aspect that could be clarified.

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## Appendix

**Intervjuguide**

*Innledning: Forskningsprosjektet 1,2,3! skal bidra til utvikling av gode, rimelige boliger med høye energiambisjoner for flyktninger som har fått opphold og som skal bosettes i Melhus Kommune. Boligen skal være en god og verdig plass å bo samtidig som boligen skal kunne være kostnadseffektiv og ha overføringsverdi til andre kommuner som trenger å tilby husrom til vanskeligstilte grupper i løpet av kort tid.*

**Din bakgrunn**

Hvor kommer du fra? Hvor lenge har du bodd i Norge? Hvor lenge har du bodd i Melhus kommune?
Hva er din yrkesbakgrunn og hva jobber du med nå?
Hvem bor du sammen med nå – har dette endret seg? Vil det endre seg?

**Bolig bakgrunn**

Hvor bodde du før – byer, land
Hva slags boliger har du bodd i? stor, små, leilighet, hus

- Hvor mange rom?
- Hvor mange personer bodde du sammen med?

Hvor lå det i byen? Sentrum, distrikt, nær familie, skoler
Trivdes du/ eller ikke? Hvorfor
Er boligene i Norges annerledes? Er det kvaliteter fra tidligere boliger som du savner?

**Boligtildeling**

Kan du beskrive tildelingsprosessen? Har du vært med på boligtildelingsprosesser før?
Hva sier andre du kjenner om prosessen? Har de råd eller erfaringer?

**Beskriv boligen du bor i**

Hva slags bolig har du i dag? Og hvorfor bor du akkurat her?
Hvem bor du sammen med?

Er boligen funksjonell?

- Nok plass – hvor stor er boligen – antall m2 og antall rom
- Planløsning
- Åpen løsning
- Badet
- Hvor mange soverom?

Hvor mye koster det å bo i leiligheten? Husleie, strømregninger osv.
Er boligen komfortabel? God temperatur og luft
Er boligen attraktiv? Utsikt, farger, innredning, materialer
Føler du deg trygg i boligen? Sikkerhet, privatliv
Hvor ligger boligen i Melhus kommune?

Er det nær servicefunksjoner
Offentlig transport
Skoler
Rekreasjonsmuligheter

**Hva slags bolig ønsker du i framtiden?**

Nytt eller gammelt hus?
Noe du savner fra tidligere erfaringer?
Vil du fortsette å bo i Melhus kommune?
Er andre du kjenner fornøyd med boligen sin? Har de råd og erfaringer?
Har du forslag til hva en bolig bør ha med og hvordan den skal se ut?

# 1, 2, 3 HOUSING! GOOD, AFFORDABLE AND ENERGY EFFICIENT HOUSING FOR REFUGEES

This analysis has considered two aspects associated with homes for refugees who have been given permission to settle within Norwegian municipalities:

- How do refugees experience the homes they have been allocated?
- What kind of solutions should municipalities choose when developing housing for the socially disadvantaged, enabling inhabitants to be energy-efficient on a tight budget?

Melhus municipality is the case presented in this analysis. Refugees and municipal employees were interviewed about housing preferences and housing allocation in the municipality.

In addition an analysis was done about the energy saving potential and costs associated with three different scenarios based on the use of different technologies, such as heat pump, solar cells and solar collectors. The example used is a construction project in Melhus municipality where housing for the socially disadvantaged is planned. The results offer municipalities the basis for choosing solutions when planning homes for the socially disadvantaged that are cost efficient and energy-friendly.

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