NTNU – Trondheim
Norwegian University of
Science and Technology

Energy analysis and experience obtained from the first passive house area in Norway

Lejla Selimovic

Master's Thesis
Submission date: March 2014
Supervisor: Natasa Nord, EPT

Norwegian University of Science and Technology
Department of Energy and Process Engineering

Norwegian University of
Science and Technology

Energy analysis and experience obtained from the first passive house area in Norway

Selimovic Lejla

Submission date : March 2014
Supervisor : Natasa Djuric

Norwegian University of Science and Technology
Department of Energy and Process Engineering

"What's the use of a fine house if you haven't got a tolerable planet to put it on?"

Henry David Thoreau, 1817-1862

NTNU
Norwegian University
of Science and Technology

Department of Energy
and Process Engineering

EPT-M-2013-138

MASTER THESIS

for

Lejla Selimovic

Autumn 2013

Energy analysis and experience obtained from the first passive house area in Norway

Energianalyse og erfaring fra det første passivhus boligområdet i Norge

Background and objective

In Trondheim, a residential building area has been built based on the passive house standard. The area of 28 000 m^2 consists of row houses and buildings. Part of the flats has been in use for more than a year. The area is connected to the district heating system. This passive house area is the most north passive house area in Norway. Much data including building documentation and energy bills are available for the study. It is important to analyze such data to increase the knowledge of this building type. The aim of the study is to organize information about the flats and define the relevant energy use indicators. The energy use indicators can help to encourage our knowledge and improve our experience for future projects. Application of the statistical methods can help in this work. Student can use both Excel and MATLAB for the analysis. The obtained results have to be compared with the results on similar projects. Based on the results, a comparative analysis on possible energy use should be performed.

This master thesis has aim to analyse energy use of the passive house area in Trondheim. The student can use Excel or some other relevant tool to analyse the data.

This assignment is realised as a part of the collaborative project "Sustainable Energy and Environment in Western Balkans" that aims to develop and establish five new internationally recognized MSc study programs for the field of "Sustainable Energy and Environment", one at each of the five collaborating universities in three different WB countries. The project is funded through the Norwegian Programme in Higher Education, Research and Development in the Western Balkans, Programme 3: Energy Sector (HERD Energy) for the period 2011-2013.

The following tasks are to be considered:

1. Literature review on building energy use in residential buildings and driving variables of residential building energy use.
2. Collect building data and energy use data. Design data and monthly energy bills for electricity and district heating are available. Organize data in a suitable way for analysis.
3. Choose one or few statistical methods to analyse building energy use data. Analyse the collected data. Define driving variables of the energy use.

4. Compare obtained results on the energy use with other similar projects.
5. Present and discuss the results.

-- " --

Within 14 days of receiving the written text on the master thesis, the candidate shall submit a research plan for his project to the department.

When the thesis is evaluated, emphasis is put on processing of the results, and that they are presented in tabular and/or graphic form in a clear manner, and that they are analyzed carefully.

The thesis should be formulated as a research report with summary both in English and Norwegian, conclusion, literature references, table of contents etc. During the preparation of the text, the candidate should make an effort to produce a well-structured and easily readable report. In order to ease the evaluation of the thesis, it is important that the cross-references are correct. In the making of the report, strong emphasis should be placed on both a thorough discussion of the results and an orderly presentation.

The candidate is requested to initiate and keep close contact with his/her academic supervisor(s) throughout the working period. The candidate must follow the rules and regulations of NTNU as well as passive directions given by the Department of Energy and Process Engineering.

Risk assessment of the candidate's work shall be carried out according to the department's procedures. The risk assessment must be documented and included as part of the final report. Events related to the candidate's work adversely affecting the health, safety or security, must be documented and included as part of the final report.

Pursuant to "Regulations concerning the supplementary provisions to the technology study program/Master of Science" at NTNU §20, the Department reserves the permission to utilize all the results and data for teaching and research purposes as well as in future publications.

The final report is to be submitted digitally in DAIM. An executive summary of the thesis including title, student's name, supervisor's name, year, department name, and NTNU's logo and name, shall be submitted to the department as a separate pdf file. Based on an agreement with the supervisor, the final report and other material and documents may be given to the supervisor in digital format.

☐ Work to be done in lab (Water power lab, Fluids engineering lab, Thermal engineering lab)
☐ Field work

Department of Energy and Process Engineering, 16. September 2013

Olav Bolland
Department Head

Natasa Nord
Academic Supervisor

Research Advisors: Prof. Vojislav Novakovic
Prof. Fikret Alić, University of Tuzla

Preface

This report represents my Master Thesis, conducted the last semester in the MSc Sustainable Energy and Environment, class of 2012. This thesis is written at the Department of Energy and Process Engineering at the Norwegian University of Science and Technology, NTNU, in Trondheim, Norway, the fall 2013.

We wanted to achieve new knowledge about a passive houses, and chose therefore to analyze project at Miljøbyen Granåsen in Trondheim, Norway.
The objective of this thesis was to acsess the benefits of using a passive house. This master thesis has also objective to analyze energy use of the passive house area in Trondheim.
The thesis has been quite challenging since the gathering of all necessary data.
It has been really interesting to analyzing a Norwegian passive house with respect to environmental impacts, and the learning outcome from the building industry has been great. In the end, I'm very satisfied with the assessment and the overall results.

This project is mainly for project at Miljøbyen Granåsen , but can also be used as an inspiration for anyone who wants to build a passive house.

I would like to thank everybody who has provided relevant data and support for this project. People in the Heimdal Development Company who is producer of building products were very helpful in providing data.

A special thanks go to my supervisor, Prof. Natasa Nord from NTNU for great guidance and good cooperation.

Lejla Selimovic
Trondheim, Norway
December 2013

Abstract

The engagement in Low energy and Passive houses in Norway has increased during the last years. A low energy building has a total net energy demand not more than 100 kWh/m²yr (this includes all the electricity consumed in the dwelling), which indicates a space heating demand close to 30 kWh/m²yr. An average dwelling unit in Norway consumes totally 214 kWh/m²yr end energy. This is nearly the same as net consumption and primary energy consumption because the greater part of the Norwegian housing stock is heated by hydro electricity power. The national building code has since 1997 required a space heating demand about 60-90 kWh/m²yr. From august 2009 it was limited to 40-60 kWh/m²a. This is better than in Germany. However, the energy consumption related to domestic hot water and especially to lighting and technical equipment is in Norway much higher than in central Europe. The main reason is not dark winters, but very cheap electricity over the decades after the Second World War [Hahn 2005].
In Norway buildings represent approximately 40% of the total energy consumption, 22% in the residential sector and 18% in the non-residential sector *(Sartori, Wachenfeldt, & Hestnes, 2009).*

Several locations in Norway have cold or extremely cold weather conditions compared to Central Europe. A valid question is if the Passive House definitions of 15 kWh/(m²yr) and 10 W/m² is possible and can this apply for such cold climate.

We got the chance to work on a specific project Miljøbyen Granåsen to improve our knowledge about this subject. The objective of this study is to evaluate is it planed energy use achieved, and to look at different reasons for when energy use is not as expected. 29 houses were studied, of which 14 detached houses and 15 terraced houses.

For verification, it was provided comparison of measured energy use in first 12 months and estimated energy use. Use of electricity and heating energy was provided on monthly basis from Heimdal Development Company. It was not possible to get data about energy use by end users, so that was estimated in this paper.

The results show that houses achieve higher energy use than estimated, some of them with really high energy use for passive houses. Only two terraced houses achieved estimated energy use. The results show that energy use is dependent on occupants behavior and that they should be well-motivated and more „energy aware“. Changes in usage patterns are not considered, or corrected, and they also has a big impact on energy use. Users does not inform always about changes in houses. For some houses we got information about installed additional, socket, heating system, ventilation, etc, and these are good indicators of higher energy use.

The ultimate goal of this paper is to encourage more efficient energy use of houses. It is important that issues mentioned in this work be more studied and discussed to face this challenge.

This assignment is realized as a part of the collaborative project "Sustainable Energy and Environment in Western Balkans" that aims to develop and establish five new internationally recognized MSc study programs for the field of "Sustainable Energy and Environment", one at each of the five collaborating universities in three different WB countries. The project is funded through the Norwegian Program in Higher Education, Research and Development in the Western Balkans, Program 3: Energy Sector (HERD Energy) for the period 2011-2013.

Table of Content

List of figures

List of tables

1. **Introduction**

1.1 Problem background

Green city Granåsen is a new building project in Trondheim, which includes detached and terraced houses, as well as apartment buildings.
Granåsen is part of the EU project *Concerto Eco-City.* This is a project that has intended to develop and demonstrate energy solutions in homes through planning measures, structural measures and energy efficient operation.
All homes in the green city Granåsen are bulit by passive standard (NS 3700).

Today about 2/3 of all energy consumption in households originates in heating and hot tap water supply. This illustrates the relevance and reduction potential in this field.
ECO-City is part of the CONCERTO initiative of the European Commission, focusing on the development and demonstration of good and efficient energy solutions on municipal level. The ECO-City project especially is dedicated to working with joint developments in Scandinavia and Spain.
The objective is to strengthen the technological and institutional basis for a community wide utilization of efficient and economic energy concepts. The second aim is to develop projects that demonstrate solutions and serve as knowledge basis and incentive for further development in selected communities in Spain, Denmark/Sweden and Norway. The three participating European ECO-Cities are: Tudela (Spain), Helsingborg/Helsingør (Sweden/Denmark) and Trondheim (Norway).
The overall approach is defined by the aim of using the reduction potential of the demand before designing the sources for supply. This allows an optimization of the supply solution and raises the level of efficiency as well as sustainability. The focus is on energy efficient technologies, integrating a maximum of renewable energy sources. *(ECO-City Trondheim)*

The objective of this study was to analyse of energy use in family houses, regarding reaching the passive house standard. We started with sketches of houses and data on energy use.
The analysis was done by Data Analysis Tool.

The goal of this project is to deliver a report that reflects the use of passive house in most north passive house area in Norway with the rough weather conditions and low solar radiation.

1.2 The objective and scope for this thesis

The objective of this study was to access benefits of building a passive house.
In Norway it is at present stage an ongoing discussion around the passive house technology and it is under consideration whether to introduce a passive house standard for all new buildings by 2020. The passive house technology is supposed to be energy efficient, but it is important that the extra use of energy in the production phase not exceeds the environmental benefit of the energy savings during the use phase of the building.
The overall goal of this study is to evaluate the possible benefit of passive house technology.
We should answer the question whether the passive house with a consumption of 15 kWh / (m^2) are feasible for such a cold climate conditions. This work was made with comparisons between obtained and measured energy use. The number of members in the houses and the technical devices used are varied so that the energy consumption in different houses need to be different. All houses are connected to the district heating system. This research will specifically focus on the factors that affect energy use. The analysis included use of electricity and heating energy use.

It is beyond the scope for this thesis to go in depth in this issue, but some general most theory and heat energy calculations are presented to give a brief overview as this is a topic related to the passive house construction dryer energy demand.
In this paper we analyzed 29 passive houses.

The company wishes that name of houses remain anonymous.
Expected results and accomplishments results should be compared to all the buildings to see if savings are achieved as planned.

1.3 The master thesis structure

The structure of this thesis is based on the defined goals and research methodology and is divided into ten chapters. Chapter 1 introduces an overall view of this study. It contains the field of research, the problem definition, the purpose and objectives of the work. Further this chapter displays what are the research questions and finally the thesis outline.
Chapter 2 represents research methodology.
In chapter 3, theory in the field of energy use is presented and discussed to identify the knowledge gaps to be explored in the research. The current Norwegian standards in construction of passive houses are also summarized.

In chapter 4 all houses types and the construction area are described. The functional unit and its system boundaries are also presented
Chapter 5 presents calculated energy needs for houses and 6 includes analysis of actual energy use in houses.
Chapter 7 is about domestic hot tap water use.
In chapter 8 is described domestic electricity use by end-users.
Chapter 9 presents radiator heating effect.
Chapter 10 shows comparison between measured and calculated energy use.
Chapter 11 presents conclusions and knowledge gained from the research.
Chapter 12 is about future work.

1.4 The thesis restrictions

Unfortunately, the collection of data was limited. For buildings that are used for analysis in this study, it was possible to detect only total monthly energy use, and not use by energy carriers (electrical equipment, domestic hot water, etc.) Also we did not have accurate information about radiators heating effects, hot water supply, about installed devices in all homes and number of household members.

For some months, there were no information about energy use, so that they are not representative. There was lot of information that we could not get because of data protection rules.

2. Thesis research methodology

Influencing factors on the selection of the strategy research are: the research questions, the influence of the environment and actual events.
This chapter describes methodology that is performed in this study.

First phase is a design phase and contains: literature review, selection of cases and design of data collection protocol. To get better introduced with the topic, review of relevant literature was conducted and logically summarized.
Many books and scientific papers were reviewed to get an idea of background for writing of this thesis. For example, work: *Does Sustainable Building Technology Matters to Home Buyers* wrriten by Anna Carina Carlsson gaves useful information about decion of people in Granåsen to buy passive house, and I found out that reason for this was not pro-environmental values, beliefs and norms but location of the houses as well as the limitation of the housing market was the strongest determinant factors.
The NS3700, *Kriterier for passivhus og lavenergihus. Boligbygninger.* 2010, Standard Norge gaves me basic information about reqruitments for passive houses in Norway.
From another useful book, *Passive Houses in Sweden*, written by Ulla Janson (2010) I took information about energy demand,and instructions for calucation of domestic tap water supply.
Work: *Appliance Energy Use and Cost in Alaska*, written by Richard Seifert, gaves me direction for calculation of energy use for appliances. There are many other books, scientific works that are used to finish this thesis.

Next phase of research is data collection and analysis. Necessary data are provided by people from company *Heimdal Eiendomsmegling AS*.
Fourt phase represents making of datebase with all collected data about energy use.
The following phase is analysis of monthly electricity and heating energy use for first year.
Sixth phase is calibration of hot tap water use and electricity use by end-users.
In the seventh phase was provided software simulation of heating effect of radiator.
The energy simulation software *Energy 2D* was used to prove if it is possible to achieve thermal comfort in houses with only one radiator on the floor.
Energy 2D is developed by Dr. Charles Xie, at the Concord Consortium based in Concord, Massachusetts, USA. This is good tool for thermal analysis. It is powerful, easy and intuitive to use.
The purpose of this work was not to modify theory but to increase awareness of the importance and to provide better understanding of studied topics. At the end of the research is given a report with results.
Figure 2-1 displays all phases included in this work.

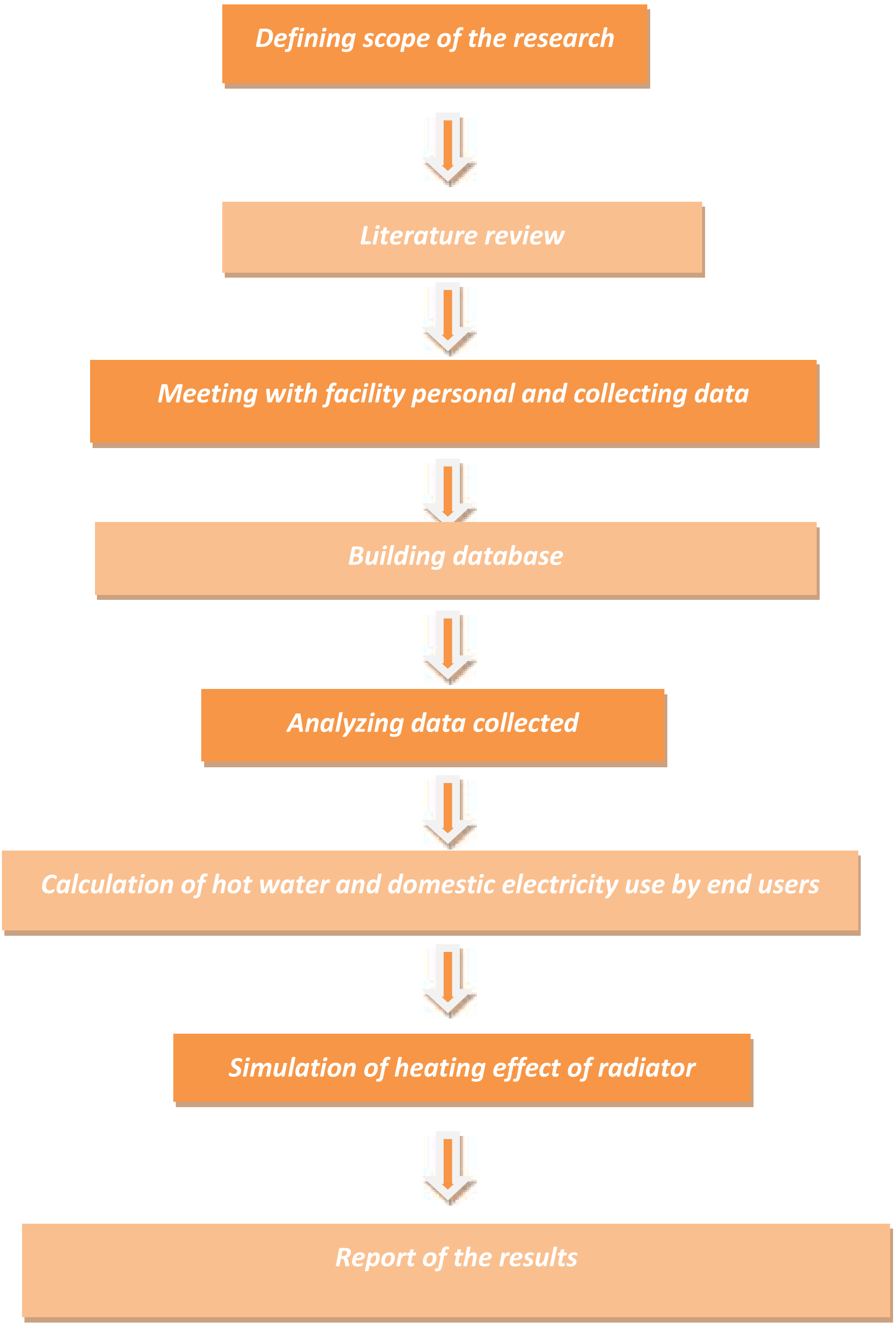


Figure 2-1: Thesis research methodology

3. Concept review

The aim of this chapter is to provide a general overview of the key concepts based on the literature review. The chapter begins with description of information about Norwegian Building code and Standard Norway. Next it presents observed project: green city Granåsen with its specifications and illustrates climatic conditions in Trondheim.

3.1 The Norwegian Building code and Standard Norway

The definition of a passive house is "a *building in which thermal comfort [EN ISO 7730] can be guaranteed by post-heating or post-cooling the fresh-air mass flow required for a good indoor air quality." (Dr. Wolfgang Feist,*2007). This concept was developed in Germany May 1988 by Bo Adamson and Wolfgang Feist, and has since then been widely and successfully used in Germany and Austria. Some basic principles are shown in Figure 3-1.The main criterion is that the annual energy used for space heating should not exceed 15 kWh/m^2.

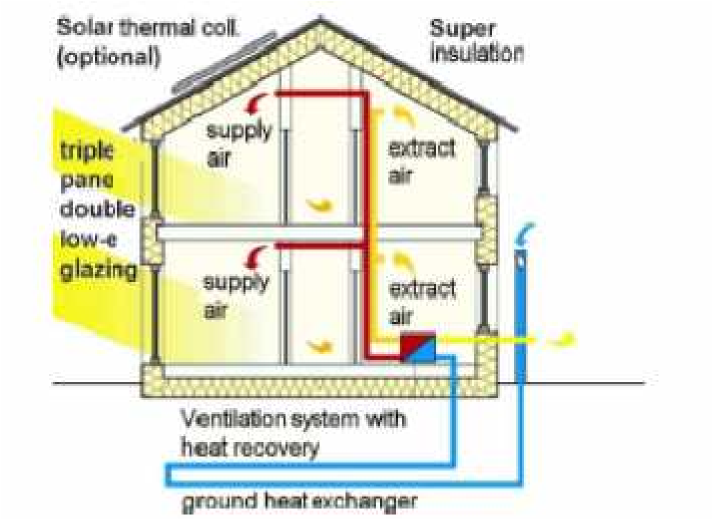


Figure 3-1: Basic principles of a passive house (Passivhaus, 2011)

Passive House is a concept introduced by Passivhaus Institut in Germany. Passive houses has become widespread and a success in Germany, Austria and later in several other European countries. Strict requirements for design and constructions in these countries has led to passive houses is recognized as environmentally friendly buildings with very high quality, with good indoor air quality and extremely low energy need.

In Norway there are two regulating building requirements to follow; The Norwegian building code and the building standards.
The Norwegian building code is called the Planning and Building Act (TEK) and this sets parameters for how Norwegian buildings of today should be built.
In the last years have two new revisions been made;

1) At 01.02.2007, new energy requirements were introduced. The code is often referred to as TEK 07. It was a 2.5-year transition period. The new requirements became mandatory from 08.01.2009.

2) At 07.01.2010 the revised regulations were changed. New technical building regulations entered in force, often referred to as TEK 10. TEK 10 resulted in some changes in demand for energy efficiency and energy supply.

It is a one year transition period, until 01.07.2011, where the developer can choose whether the project should follow TEK 10 or TEK 07. In this study TEK 07 will be used as a basic.
When it comes to Standards Norway (SN), this is a private and independent member organization, and is one out of three standardization bodies in Norway *(Standards Norway)*. Standards Norway is responsible for standardization activities in all areas except the electro technical field and the telecommunications field.
Standards Norway is the national member of the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN).

3.1.1 The Norwegian passive house standard NS 3700

In the spring of 2010, a new Norwegian standard for low-energy and passive houses was founded under the name NS 3700. The standard provides guidance for planning, construction and evaluation of residential buildings with a low energy need and implementation of renewable energy *(Standards Norway).*
Germany has been the leading country when it comes to passive house technology and the passive house standard is based on the German standard made by Passivhaus Institutt. The reason to say that the house is passive, is that it uses the energy that whatever is present in the building. This energy includes the heat from computers and other electrical appliances, as well as the heat emitted by the users of the building.
Energy consumption is reduced by passive measures where important items are extra insulation, tight construction and compact body, high-insulating windows and normally a good ventilation system with heat recovery. Secondary attempts are to exploit passive solar heating in an efficient manner (most windows facing the sunny orientation).
Finally, an energy source and heating solution that is adapted to the low demand for heating is chosen.
It is emphasized that the Norwegian standard for passive houses does not have to deviate too much from the criteria used in Sweden and Europe. Nevertheless, it is taking into account special Norwegian conditions such that a large proportion of residential buildings consist of smaller homes and that a significant portion of the housing stock is built in especially cold climates *(2010, Standard Norge).*
For example, when considering energy needs for a building, the standard requires energy calculation based on local climate where the house is to be constructed.

3.1.2 Building technical requirements

There are great differences regarding the building technical requirements in a conventional TEK house and a passive house. Some of the main premises for the two standards will be presented in this chapter.

Table 3-1 shows a comparison of the lower requirement of current regulation and the passive standard of total energy needs, also called the energy framework, for residential buildings. The unit in the table is kWh /m^2 heated usable floor area per year.

Table 3-1: A comparison of the energy frame from TEK 07 and the passive house standard

	TEK 07	*Passivhouse standard*
	125+1600/m^2	
Residential house	1600	80

Table 3-2 shows the proposed insulation requirements, while Table 3-3 and Table 3-4 show specific U-value requirements concerning the construction and windows.The thermal transmittance, or U-value for a component, is a measure of how good the heat insulation is.

The U value is measured in W/m^2 K, and indicates the amount of heat per unit time passing a square meter of construction at a temperature difference of one degree Kelvin between the two sides of the structure. In short, a low U-value provides good heat insulation.

Table 3-2: Insulation requirements from TEK 07 and the passive house standard

Construction	*TEK 07*	*Passivhouse standard*
Outer walls	250 mm mineral wool	300 - 450mm mineral wool
Roof	350 mm mineral wool	450 - 550mm mineral wool
Ground floor	200mm exp. polystyrene	300 - 350mm exp. polystyrene

Table 3-3: U-value requirements of TEK 07 and the passive house standard

Construction	*TEK 07 (W/m^2 K)*	*Passivhouse standard (W/m^2 K)*
Outer walls	0,18	0,12
Roof	0,13	0,07-0,10
Ground floor	0,15	0,07-0,10
Normalized cold bridge	0,05	0,03

Table 3-4: Window requirements from TEK 07 and the passive house standard

	TEK 07	*Passivhouse standard*
Type	Insulated frame and two-layer energy glas with argon in the cavity, or common frame with triple energy glas and argon in the cavity	Insulated frame and triple energy glas with argon in the cavity
U-value	1,2 W/m^2K	0,8 W/m^2K

The density or tightness of the building envelope can be described by a “leakagenumber”, which is the air change rate measured at a pressure of 50 Pa. This parameter is called N50 and is presented in Table 3-5.

Table 3-5: Window requirements from TEK 07 and the passive house standard

	TEK 07	*Passivhouse standard*
	(air change/h)	(air change/h)
Density,building body (N50)	2,5	0,6

Table 3-6: Standardized energy requirements regarding lighting, technical equipment and hot water in a dwelling

	TEK 07
Energy post	(kWh/m^2yr)
Lighting	17
Technical equipment	23
Hot water	30

Main requirements regarding the ventilation system is presented in Table 3.7. An important feature of the ventilation systems is the specific fan power, also called SFP factor.
This factor is measured with the unit kW/ (m^3/s) and provides a measure of the ventilation fans' efficiency. For conventional homes, is the SFP factor according to the regulations set to be 2.5 kW/(m^3/s) (*2007, Standard Norge).*
According to the passive house standard 1.5 kW/ (m^3/s) or less is preferred.
Heat recovery is the amount of energy that is recovered after it is taken out from the hot reservoir. The air change rate needed is 1.2 $m^3/(hm^2)$ and is the same for the two standards.

Table 3-7: Requirements regarding ventilation

Spesification, ventilation	*TEK 07*	*Passivhouse standard*
SFP factor	2,5 kW/(m^3/s)	1,5 kW/(m^3/s)
Heat recovery	70 %	80%, balanced
Air change rate	1,2 $m^3/(h\ m^2)$	1,2 $m^3/(hm^2)$
Energy use	-	4 kWh/m^2 yr

4. Project green city Granåsen

The aim of this chapter is to provide a general overview about observed area.
In this chapter, all houses types and the construction area are described. The functional unit and its system boundaries are also presented.
South of Trondheim was in 2012 completed 17 houses in the passive construction. In detached part of the residential green city Granåsen will be a total of approximately 300 units 300 homes of various housing types that everyone should adhere to the passive house standard. *(http://arkitektur.no/miljobyen-granasen-eneboliger)*

Annual mean temperature of 4.9 °C
Design winter temperature of -19 °C
Annual global horizontal solar radiation of 107 W/m^2.

Table table presents estimated energy demands for heating.

Table 4-1 Energy demand for houses

	Energy demand
Space heating	1353 kWh/yr [16 kWh/(m^{2}yr)]
DHW heating	2408 kWh/yr [30 kWh/(m^{2}yr)]
Total thermal demand	3760 kWh/yr [46 kWh/(m^{2}yr)]

4.1 Location

Districts are located in Trondheim Angeltrøa not far from the recreation area Estenstadmarka. It's proximity to the nursery, several large jobs and proximity to public transit. The environmental center will be installed to reduce traffic on the site.
Figure 4-1 shows location of green city.

Figure 4-1: Location of green city Granåsen (http://maps.google.no/)

4.2 Weather conditions

Climate has an important role in energy analysis of buildings. In Norway where climate is characterized like cold and wet it is difficult to achieve thermal comfort inside the buildings. Analyzed year was 2012, so climate date for this year will be presented in this chapter.

Day light has also big impact on energy use. Southern Norway never has continuous daylight, though it averages 19 hours of daylight a day in midsummer. In winter, Norway has similar periods of continuous darkness. In the northernmost areas of the country the sun never rises above the horizon for about 2 months. Southern Norway has some daylight each day, though it receives only about 6 hours of daylight a day in midwinter.
(http://www.weatheronline.co.uk/reports/climate/Norway.htm)

The Norwegian Meteorological Institute (MET, 2011) is responsible for registering climate data from weather stations all over Norway. For Trondheim there is a several weather stations. A normal temperature is defined by MET as the mean annual temperature in a period of 30 years.

The next graph shows the climate in Trondheim, Norway in metric units and the second in English units. The climate graphs depict monthly average temperatures, precipitation, wet days, sunlight hours, relative humidity and *wind speed*. We can see that max. temperature was in July, and min in January of 2012. This year did not have extreme temperatures. Averages sunlight hours were about 5 hours/day.

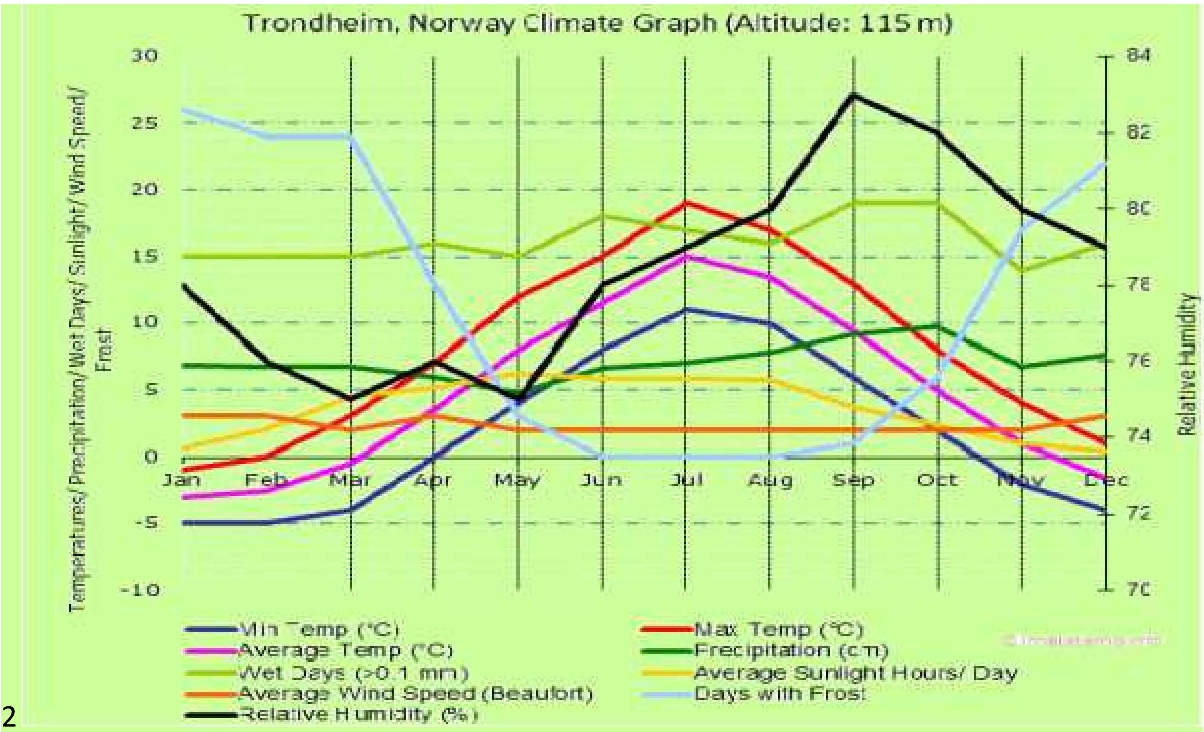


Figure 4-2: Trondheim, Norway Climate Graph.
(http://weatherspark.com/history/28896/2012/Stj-rdal-Nord-Trondelag-Norway)

Outdoor temperature, humidity in Trondheim, in 2012 are given in Figure 4-3 and 4-4 respectively. :

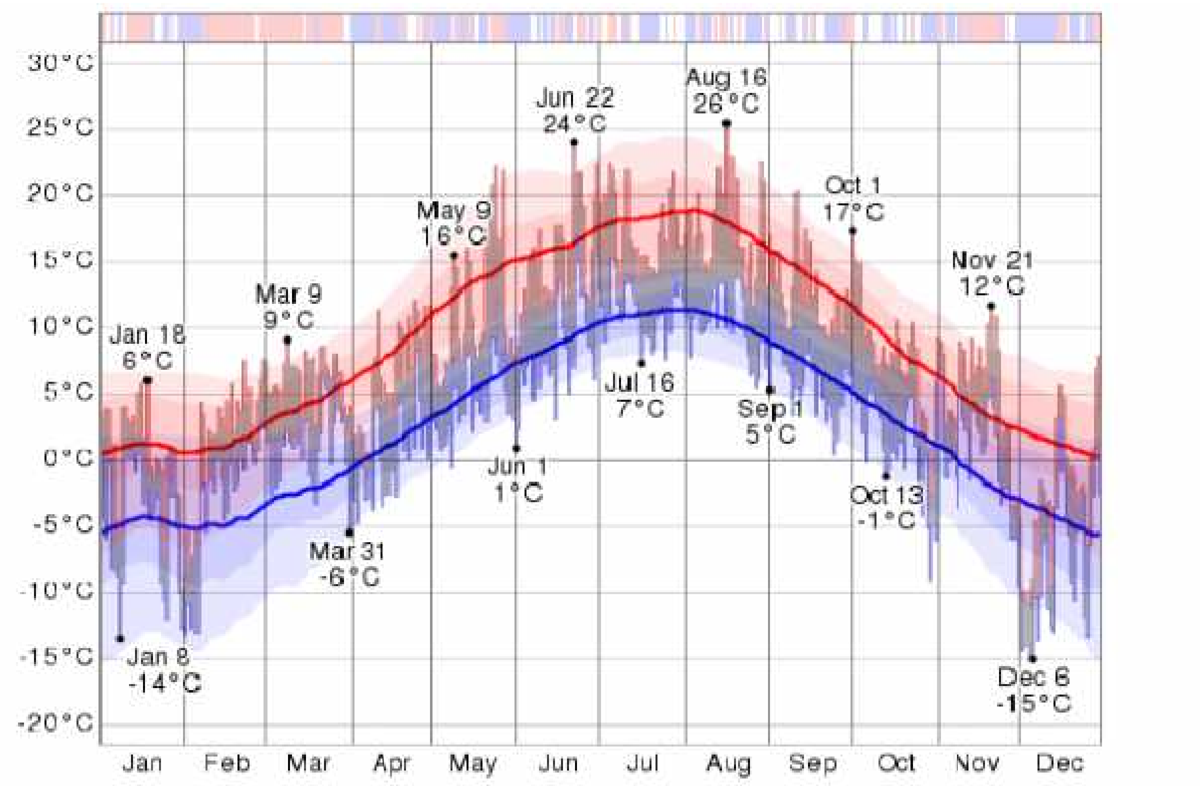


Figure 4-3: Temperature statistics for Trondheim for year 2012
(http://weatherspark.com/history/28896/2012/Stj-rdal-Nord-Trondelag-Norway)

The daily low (blue) and high (red) temperature during 2012 with the area between them shaded gray and superimposed over the corresponding averages (thick lines), and with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile). The bar at the top of the graph is red where both the daily high and low are above average, blue where they are both below average and white otherwise.

The *hottest day* of 2012 was August 16, with a high temperature of 26°C. For reference, on that day the average high temperature is 18°C and the high temperature exceeds 23°C only one day in ten. The *hottest month* of 2012 was August with an average daily high temperature of 18°C.

Relative to the average, the hottest day was November 21. The high temperature that day was 12°C, compared to the average of 3°C, a difference of 9°C. In relative terms the warmest month was March, with an average high temperature of 6°C, compared to an typical value of 4°C.

The longest *warm spell* was from February 9 to February 26, constituting 18 consecutive days with warmer than average high temperatures. The month of March had the largest fraction of warmer than average days with 84% days with higher than average high temperatures.

The *coldest day* of 2012 was December 6, with a low temperature of -15°C. For reference, on that day the average low temperature is -3°C and the low temperature drops below -11°C only one day in ten. The *coldest month* of 2012 was December with an average daily low temperature of -8°C.

Relative to the average, the coldest day was December 6. The low temperature that day was -15°C, compared to the average of -3°C, a difference of 12°C. In relative terms the coldest month was December, with an average low temperature of -8°C, compared to an typical value of -4°C.The longest *cold spell* was from November 28 to December 15, constituting 18 consecutive days with cooler than average low temperatures. The month of April had the largest fraction of cooler than average days with 73% days with lower than average low temperatures.The longest *freezing spell* was from November 29 to December 15, constituting 17 consecutive days with temperatures strictly below freezing.

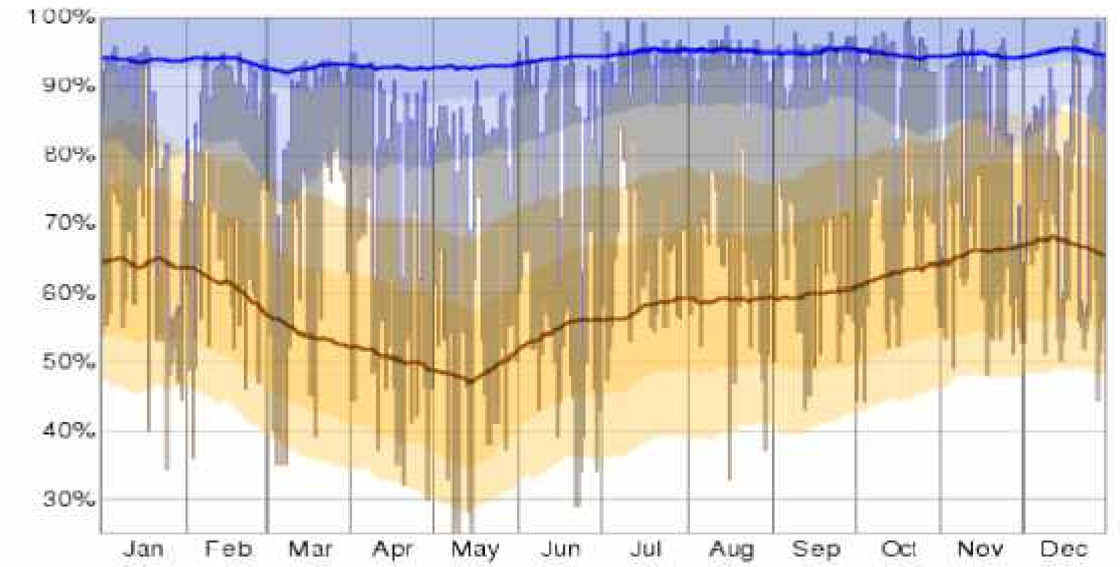


Figure 4-4: Humidity report for Trondheim for year 2012 *(http://weatherspark.com/history/28896/2012/Stj-rdal-Nord-Trondelag-Norway)*

Humidity is an important factor in determining how weather conditions feel to a person experiencing them. Hot and humid days feel even hotter than hot and dry days because the high level of water content in humid air discourages the evaporation of sweat from a person's skin.When reading the graph below, keep in mind that the hottest part of the day tends to be the least humid, so the daily low (brown) traces are more relevant for understanding daytime comfort than the daily high (blue) traces, which typically occur during the night. Applying that observation, the *least humid month* of 2012 was May with an average daily low humidity of 49%, and the *most humid month* was October with an average daily low humidity of 66%.

But it is important to keep in mind that humidity does not tell the whole picture and the dew point is often a better measure of how comfortable a person will find a given set of weather conditions. Please see the next section for continued discussion of this point.

The local weather conditions are important to take into consideration when constructing the building, and calculating required energy for the operation phase.
(http://weatherspark.com/history/28896/2012/Stj-rdal-Nord-Trondelag-Norway)

4.3 The analyzed houses

South of Trondheim was in 2012 completed 17 houses in the passive construction. Later, the 80 townhouses and 210 apartments were built in the area.
All residences are scheduled listed by passive. Granåsen is the largest residential area with passive houses in Norway.

Design of detached houses was based on a previous project developer and architect had done together. Window areas were reduced somewhat in relation to previous residence. Three different housing types were deigned and referred to as A1, A2 and A3, each with a heated area of approximately 180 m^2. All three housing types satisfy the passive requirements acc. NS 3700. The total area of the 17 units is 3082 m^2. Annual delivered energy (Oslo Climate) is calculated for each home to be about 94 kWh/m^2, divided into 33 kWh/m^2 (electricity) and 61 kWh/m^2 (thermal heating). Corresponding figures for homes satisfy minimum standards in technical regulations (TEK10/NS 3031), situated respectively: 144 kWh/ m^2, 42 kWh and 101 kWh electricity. Villas are built with 50 cm insulation in the ceiling, 40 cm in wall and 30 cm in the floor. Heating in each house is based on a radiator in every floor. Sales start for detached houses was in late August 2010 and these were completed in the beginning of the year 2011/2012. The price of detached houses ranged from 4.7 million to 5.7 million NOK.

Balanced ventilation ensures that cold outside air is heated by the warm indoor air before it enters the home. Additionally, outside air to go through a filter to remove dust and particles. Heating energy is provided by district heating (radiators) with the exception of the bathroom (electric heating in the floor). Heating is environmentally friendly for better indoor air quality and comfort. Windows with low U-value results in lower heating costs and a smoother, healthier homes. - Technical solutions: minimizined thermal bridges that will provide better indoor air quality and lower heating costs. - Technical equipment, with good quality such as appliances with high energy class. *(http://arkitektur.no/miljobyen-granasen-eneboliger).*

Figure 4-5 and 4-6 presents the facade.

Figure 4-5: The facade for detached houses

***Figure 4-6: The facade for terraced houses (**[http://arkitektur.no/miljobyen-granasen-eneboliger)](http://arkitektur.no/miljobyen-granasen-eneboliger)*

Figure 4-7 and 4-8 presents the drawing of the detached and terraced houses.

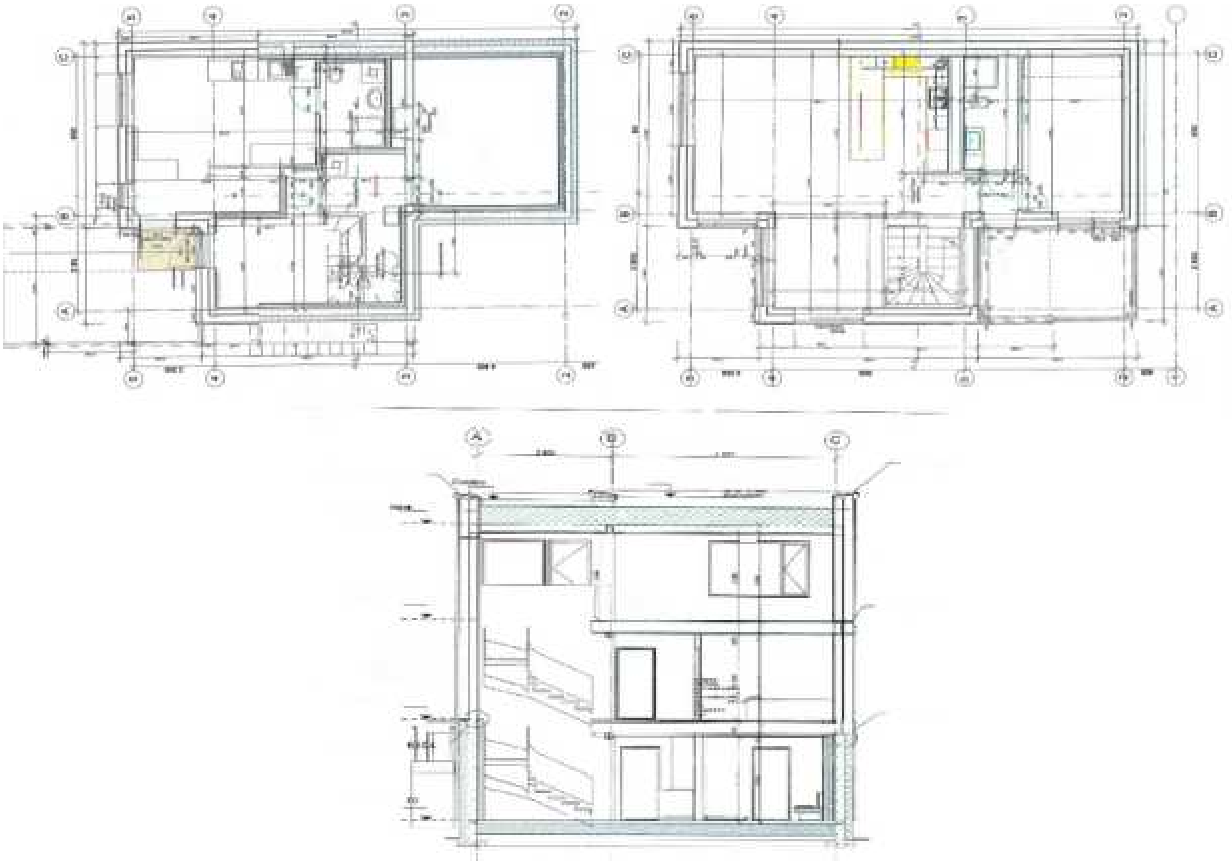


Figure 4-7: Technical drawing and floor plan for detached houses

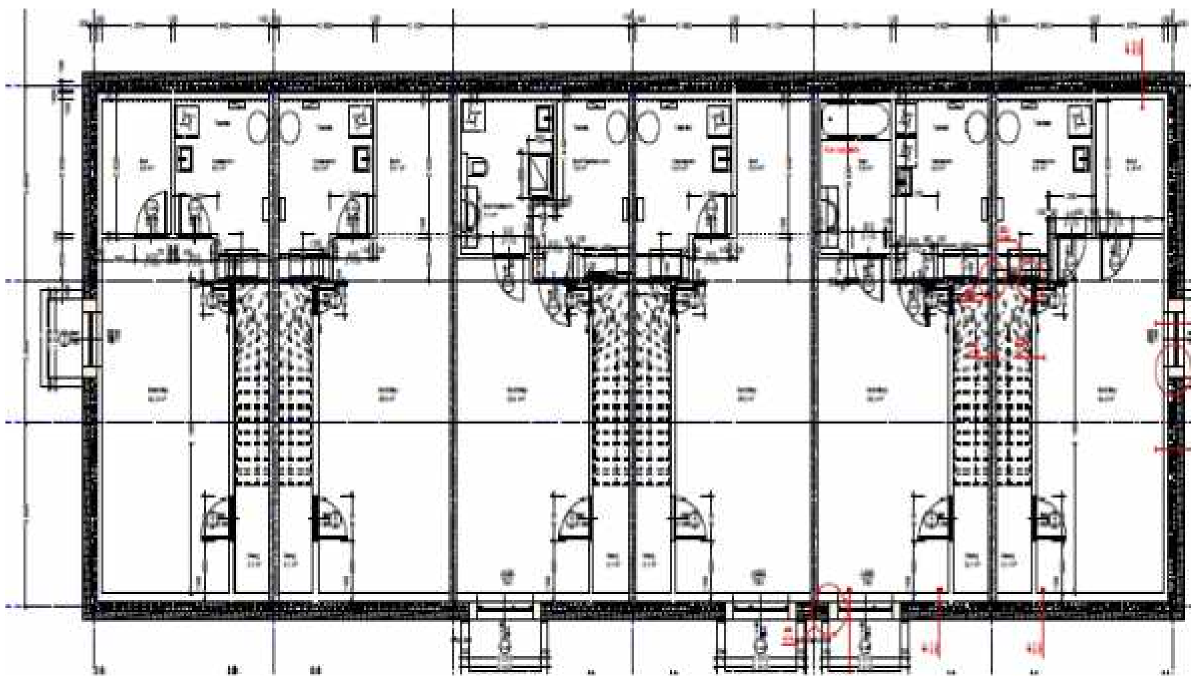


Figure 4-8: Technical drawing and floor plan for terraced houses

"Environmental town Granåsen is the largest passive fields under construction. It Has been planned 300 units, including 17 villas, 80 townhouses and 210 apartments with passive house standard. Besides detached houses have been started three other phase where the estimated migration will be for the period 2012 - 2014. Several phases are ongoing. Estimated construction of the last stage will start in 2015. SINTEF has been assigned responsibility with energy concept and has recommended that it be used district heating for both domestic hot water and heating. Due to district heating connection to the houses get energy class B. One of the inspirations for the green city Granåsen is the project Løvåshagen just outside Bergen. All homes in the green city Granåsen are built under passive standard (NS 3700). The properties are located in terrain so that they will have much access to light. *(http://arkitektur.no/miljobyen-granasen-eneboliger)*

4.3.1. Building characteristics for family houses-area B1

For better information detailed heat loss budget for buildings is presented in Table 4-1.The tables also includes element requirements from passive house NS3700:2010.

Table 4-2: Minimum element requirements, house elements and heat loss calculations

	Requirements for building components, components and leakage rate connectors. ENOVA [b]	Values used in calculationsof row houses, fields B2 Environmental town Granås (Requirement level)
U-value exterior wall [a]	≤ 0,15 W/(m²K)	0,12 W/(m²K) / 350 mm iso
U-value roof [a]	≤ 0,13 W/(m²K)	0,09 W/(m²K) / 500 mm iso
U-value floor [a]	≤ 0,15 W/(m²K)	0,12 W/(m²K) / 300 mm iso
U-value window [a]	≤ 0,80 W/(m²K)	0,80 W/(m²K)/ 3-lags iso frame
U-value door [a]	≤ 0,80 W/(m²K)	0,80 W/(m²K)
Normalized thermal bridge	≤ 0,03 W/(m²K)	0,02 W/(m²K) (calculated)
Annual average temperature efficiency	≥ 80 %	83 %
SFP ventilation factor	≤ 1,5 kW/(m³/s)	1,5 kW/(m³/s)
Leakage rate at 50 Pa, n50	≤ 0,60 h	0,60 h
Ventilation Airflow	≥ 1,20 m³/(h m²)	1,20 m³/(h m²)
Lighting	11,4 kWh/(m² h)	11,4 kWh/(m² h)
Equipment	17,5 kWh/(m² h)	17,5 kWh/(m² h)
Hot water consumption	30,0 kWh/(m² h)	30,0 kWh/(m² h)

a) U-values are calculated as the average value for the various building components.
b) A building where building parts, components and leakage rate is within the minimum requirements (Enova) will not necessarily satisfyrequirements related to heat loss figures and the highest estimated net energy for heating.

4.3.1.1 Construction details

In this chapter are presented the building details.
There is a section of each detail, where figures of U-values, heat capacity, construction details.

4.3.1.1.1 Exterior Walls

The exterior walls are constructed similar in ground floor and in first floor, except the exterior wall in ground floor towards north.
This wall have its own detail and u–value calculations. *(Miljøbyen Granås. Enebolig A1-077-vindu.smi)*

Tables below gives detailed information about structure of walls. All are costructed with well insulation and small U-walues.

Table 4-3: Exterior wall-north

Input data facade / exterior walls	
Description	Value
Name	Facing north (facade)
Total area	54.0 m²
Direction (0=North, 180=South)	45°
Int. accumulating layer Heat Capacity	Plasterboard 13 mm 2.4 Wh/m²K
Construction	48 mm double wall construction, 400 mm Insulation, U value: 0.10 W / m² K

Table 4-4: Exterior wall-south

Input data facade / exterior walls	
Description	Value
Name	Facing south (facade)
Total area	36.0 m²
Direction (0=North, 180=South)	225°
Int. accumulating layer Heat Capacity	Plasterboard 13mm 2.4 Wh/m²K
Construction	48 mm double wall construction, 400 mm Insulation, U value: 0.10 W / m² K

Table 4-5: Exterior wall-vest

Input data facade / exterior walls	
Description	Value
Name	Facing vest (facade)
Total area	65.0 m²
Direction (0=North, 180=South)	315°
Int. accumulating layer Heat Capacity	Plasterboard 13mm 2.4 Wh/m²K
Construction	48 mm double wall construction, 400 mm Insulation, U value: 0.10 W / m² K

Table 4-6: Exterior wall-east

Input data facade / exterior walls	
Description	Value
Name	Facing east (facade)
Total area	65.0 m²
Direction (0=North, 180=South)	135°
Int. accumulating layer Heat Capacity	Plasterboard 13mm 2.4 Wh/m²K
Construction	48 mm double wall construction, 400 mm Insulation, U value: 0.10 W / m² K

Figure 4-9 shows detail of the outer wall:

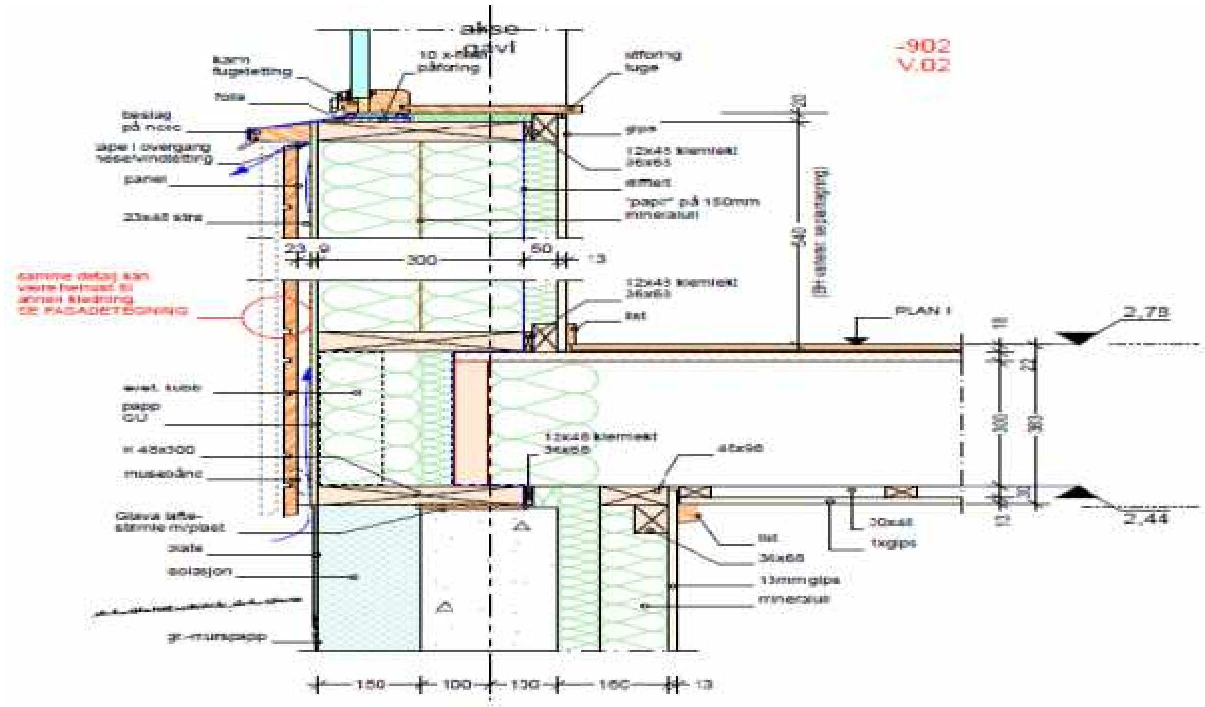


Figure 4-9: detail of the outer wall *Miljøbyen Granås. Enebolig A1-077-vindu.smi)*

4.3.1.1.2 Roof

Table 4-7 presents construction details for roof .

Table 4-7: Exterior roof

Input data roof	
Description	Value
Name	Outer roof
Total area	68.0 m²
Direction (0=North, 180=South)	0°
Roof angle	0.0 °
Int. accumulating layer Heat Capacity	0.0° 5.0 Wh / m² K
Construction	COMPACT corrugated steel, 500 mm insulation U-value: 0.09 W/m²K
Exterior absorption coefficient	0.80

4.3.1.1.3 Windows and doors

This passive house window consists of three layers of glass. Between the layers there is argon gas. The frames are insulated.

Table 4-8 to 4-10 gives details for windows and Table 4-11 for door.

Table 4-8: Window (s) Facade North

Input data window	
Description	Value
Name	v2 (Window (s) Facade North)
Number of windows	1
Window high	1.20 m
Window widht	1.50 m
Frame widht	0.08 m
Total U -value	0.77 W/m²K
Constant (fixed) Sun protection	Three layers of glass , two of which are energy- saving glass,Total SPF : 0.45
Overhang	Depth: 0.20 m Distance from window: 0.00 m
Vertical headwaters left	Depth: 0.20 m Distance from window:: 0.00 m
Vertical originated right	Depth: 0.20 m Distance from window 0.00 m

Table 4-9: Window (s) Facade South

Input data window	
Description	Value
Name	V1 (Window (s) Facade South)
Number of windows	1
Window high	0.70 m
Window widht	2.70 m
Frame widht	0.08 m
Total U -value	0.77 W/m²K
Constant (fixed) Sun protection	Three layers of glass , two of which are energy- saving glass,Total SPF : 0.45
Overhang	Depth: 0.20 m Distance from window: 0.00 m
Vertical headwaters left	Depth: 0.20 m Distance from window:: 0.00 m
Vertical originated right	Depth: 0.20 m Distance from window 0.00 m

Table 4-10: Window (s) Facade Vest

Input data window	
Description	Value
Name	V1 (Window (s) Facade West)
Number of windows	1
Window high	2.60 m
Window widht	2.30m
Frame widht	0.08 m
Total U -value	0.77 W/m²K
Constant (fixed) Sun protection	Three layers of glass , two of which are energy- saving glass,Total SPF : 0.45
Overhang	Depth: 0.20 m Distance from window: 0.00 m
Vertical headwaters left	Depth: 3.00 m Distance from window:: 0.00 m
Vertical originated right	Depth: 0.10 m Distance from window 0.00 m

Table 4-11: Exterior door

Input data exterior door	
Description	Value
Name	Door shelf (front door)
Size including frame / frame	2.1 m²
Door Type	Custom U-value:0.80 W/m²K

4.3.1.1.4 Air conditioning and electricity

Table 4-12 presents information about air conditioning.

Table 4-12: Air conditioning

Input air conditioning	
Description	Value
Climate Location	Trondheim
Latitude	63 ° 30 '
Longitude	10 ° 22 '
All times are	GMT + 1
The annual mean temperature	5.1 ° C
Mean horizontal surface solar radiation	102 W / m²
Mean wind speed	4.6 m / s

Table 4-13 describes input for energy supply.

Table 4-13 Input energy supply

Input energy supply	
Description	Value
1a Direct Electricity	System Efficiency: 1.00
	Cooling factor: 2.50
	Energy Price: 0.80 U.S. $ / kWh
	CO2 emissions: 395 g / kWh
	Share heating: 0.0%
	Share Micro. DHW: 0.0%
	Share cooling coil: 0.0%
	Percentage of space cooling: 100.0%

4.3.1.1.5 Room/zone and basement

Tables below gives details for room and basement zone.

Table 4-14 Room/zone

Input room / zone	
Description	Value
Heated floor area	175.0 m²
Heated air volume	420.0 m²
Normalized thermal bridge	0.02 W/K/m²
Heat Capacity furniture / interior	4.0 Wh/m² (medium furnished rooms)
Leakage figures (air change v. 50 Pa)	0.40 ach
Shielding in	Moderate terrain shielding
Facade Situation	More exposed facades
Operating Days	31
Operating Days	28
Operating Days	31
Operating Days	30
Operating Days	31
Operating Days	30
Operating Days	31
Operating Days	31
Operating Days	30
Operating Days	31
Operating Days	30
Operating Days	31

Table 4-15 Room/zone

Input basement item	
Description	Value
Name	Basement u.etg (basement)
Heated floor area	27.2 m²
Basement Walls Length	14.80 m Height: 2.40m Width: 0.50 m
Int. alas. layer floor Heat Capacity	Heavily floor 63.0 Wh/m²K
Floor Construction Concrete	Slab (80-120 mm), 400mm EPS / Rock wool (kl.37)
Accumulating layer wall Heat Capacity	Tung Wall 63.0 Wh/m²K
Wall Construction	Slab (80-120 mm), 400mm EPS / Rock wool (kl.37) U-value: 0.18 W / m² K
Soils	Sand / gravel Heating Capacity: 556 Wh/m³K

5. Simulated energy needs for the city Granåsen

This chapter presents the calculated energy requirements for detached and terraced houses.

This city has mean temperature of 4.9 °C, and design winter temperature of -19 °C.
Is assumed that mean inside temperature is 20 ºC.
The results are presented in the following tables. Also it will be shown an illustration of the difference of the two area versions B1 and B2.

5.1 Calculated energy needs for terraced houses

The table 5-1 shows energy and space heating needs for area B2.

Table 5-1 Simulated annual energy needs for passive terraced houses *(Miljøbyen Granås Energikonsept. Rekkehus)*

Energy budget		
Energy Post	**Energy needs [kwh]**	**Specific energy needs [kwh/m^2]**
1a Heating	6590	9,3
1b Ventilation Heating	1630	2,3
2 Hot water	21120	30,0
3a Ventilators	3089	4,4
3b Pumps	0	0,0
4 Lighting	8071	11,4
5 Technical Equipment	12311	17,5
6a Space cooling	0	0,0
6b Ventilation cooling	0	0,0
Total netto energy needs, sum 1-6	52810	74,99

Energy demand for heating + ventilation is accordingly intended to be 11.6 kWh/m^2 year.

The total energy in the same manner is calculated to be 74, 9 kWh/m^2 yr. For comparison, the corresponding requirements level townhome acc. Technical Regulations now is about 133 kWh/m^2 year (Oslo Climate). *(Miljøbyen Granås Energikonsept. Rekkehus)*

5.2 Simulated energy needs for detached houses

The table 5-2 shows energy requirement for area B1.

Table 5-2 Simulated annual energy needs for passive detached houses *(Miljøbyen Granås Energikonsept. Enebolig)*

Energy budget		
Energy Post	**Energy needs [kWh]**	**Specific energy needs [kWh/m²yr]**
1a Heating	3531	20,2
1b Ventilation Heating	482	2,8
2 Hot water	5240	29,8
3a Ventilators	767	4,4
3b Pumps	0	0,0
4 Lighting	2003	11,4
5 Technical Equipment	3055	17,5
6a Space cooling	0	0,0
6b Ventilation cooling	0	0,0
Total netto energy needs, sum 1-6	15077	86,2

For comparison, the corresponding value for the same detached acc. Technical regulations are intended to be 22.850 kWh / yr (134 kWh/m^2 yr).

Values from tables are presented in Figure 5-1:

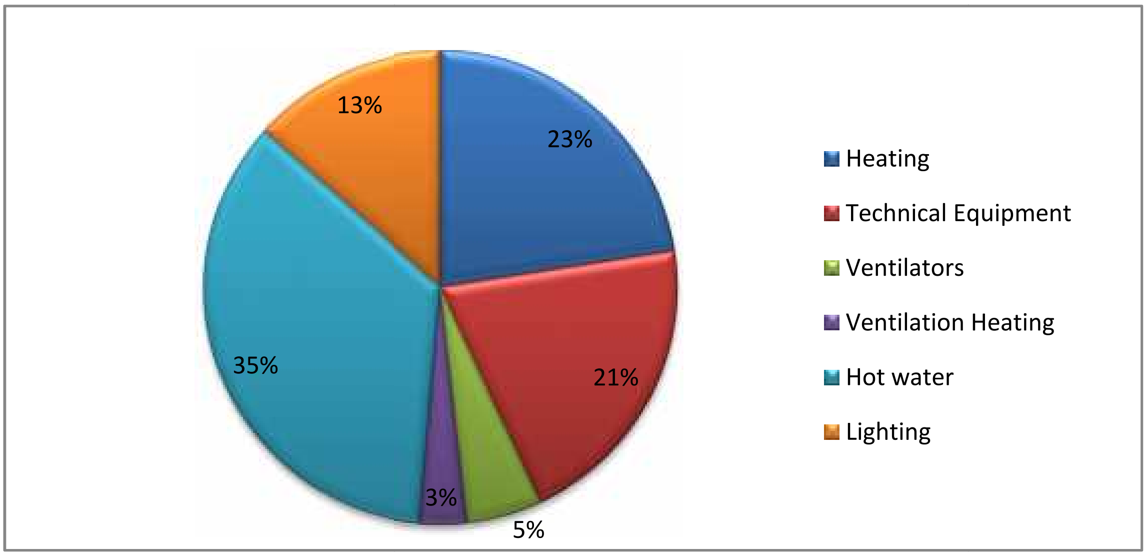


Figure 5-1: Annual energy budget for family and detached houses *(Miljøbyen Granås Energikonsept. Enebolig)*

5.2 Requirements for the leakage rate

The minimum allowable leakage rate *n50* is for townhouses set to 0.60 1 / h
For the first buildings in addition to the value measured and documented also by "tight building", i.e. before insulation and linings established. Leakage figures *n50* equal 0.60 1 / h is achieved.

• Continuous layer
Wind Sealing established as a continuous layer outer construction.
Foil applied as a continuous layer to prevent moisture entry into the structure. It should be focused on the overlap.

• Sill Membrane
Between the foundation and beams on the exterior foundation Sill Membrane must be used. This as a replacement for traditional solutions with insulating strips, foundation board etc.

• Tape
It is assumed the use of tape products related to sealing of joints and connections of sheathing to other building elements (windows and doors, transition sleepers etc.) Product Tyvek Sheathing Tape (SINTEF Technical Approval -. 2601). Requirements: Permanent adhesion.

• Cuffs
Penetrations of technical installations in the wind, and vapor control layer must also be protected against leakage using custom cuffs. *(Miljøbyen Granås Energikonsept. Enebolig)*

Figure 5-2 show simulated delivered energy, with part of directly electricity and district heating.

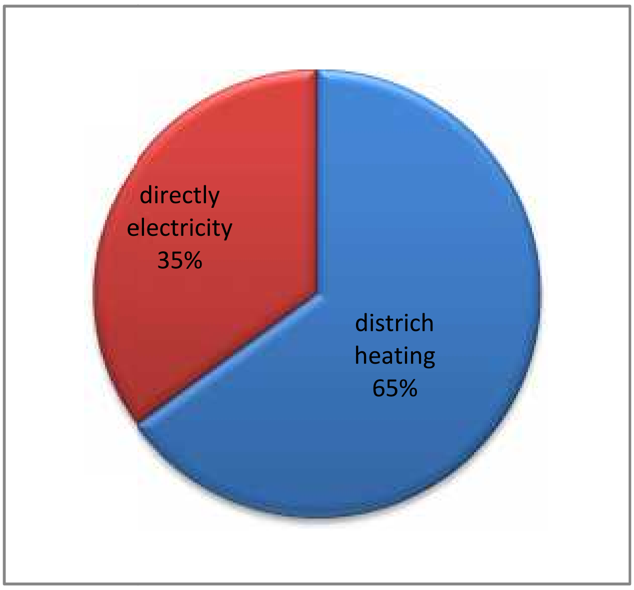


Figure 5-2: Energy delivered to the building (estimated) *(Miljøbyen Granås Energikonsept. Enebolig)*

Figure 5-3 shows heat losses by conduction, convection and radiation in building. We can see that largest losts are from windows and doors.

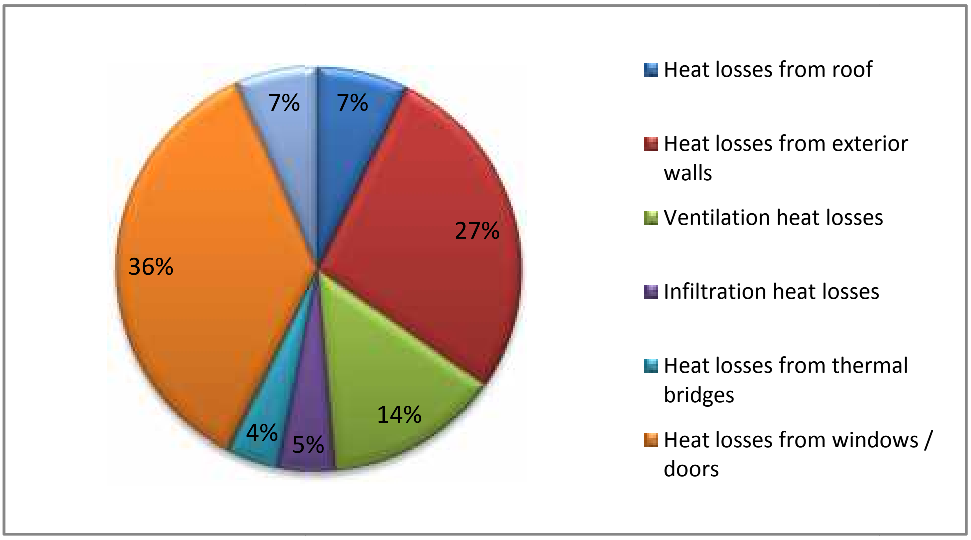


Figure 5-3: Heat losses budget (heat number) *(Miljøbyen Granås Energikonsept. Enebolig)*

Figure 5-4 shows simulated monthly energy budget by energy carriers:

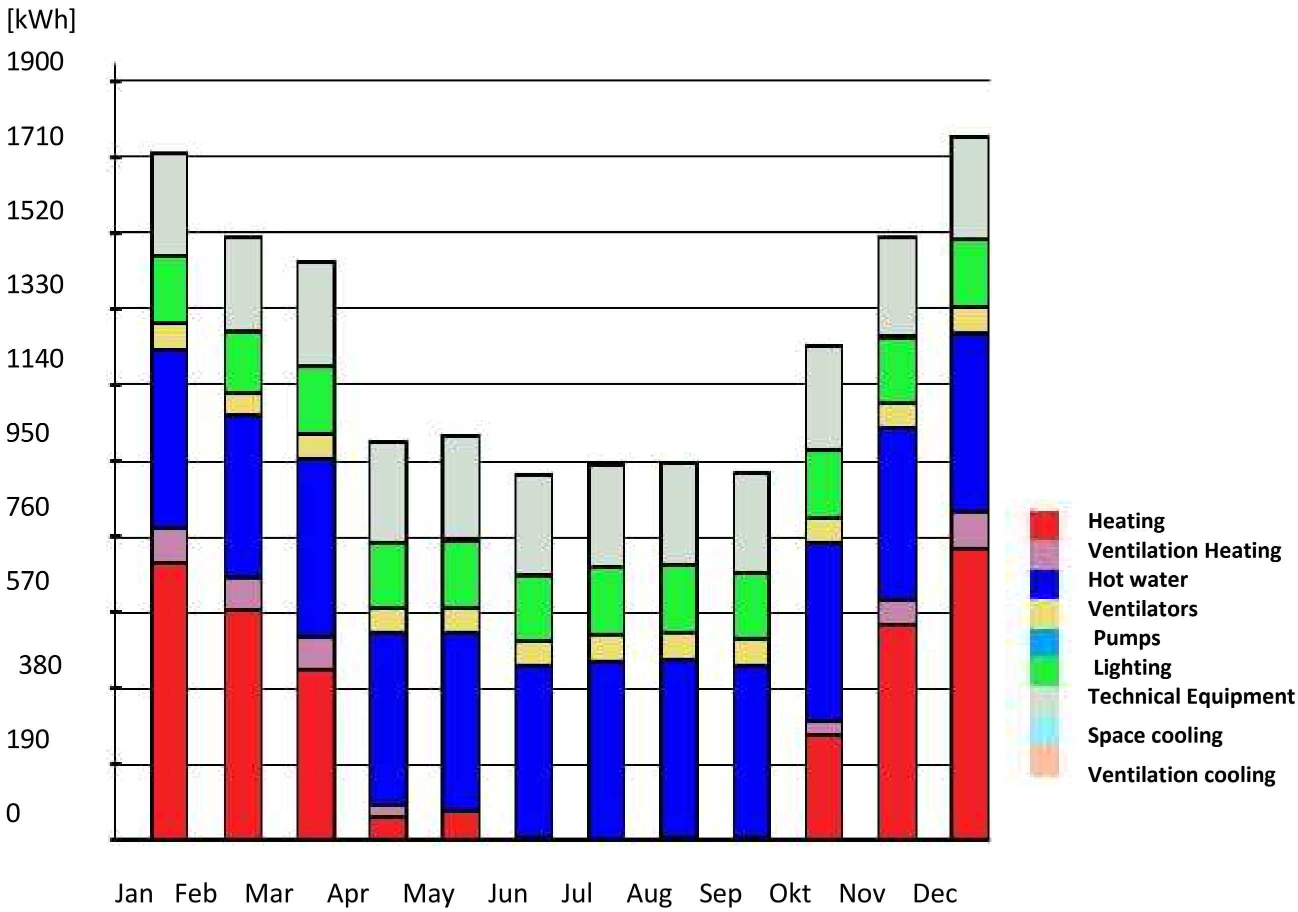


Figure 5-4: Monthly energy budget *(Miljøbyen Granås Energikonsept. Enebolig)*

6. Energy use in houses

The review of the annual energy use (in this case study, electricity and energy use for heating) is key indicator of the primary energy use in the building. It is useful to compare energy bills, which shows monthly energy use.

When analyzing the energy use in houses, several parameters must be included.
The energy use in households is dependent on several factors such as local climate, structural condition, installations, technical facilities and the use of electrical equipment.
The same type of household may have a large variation in energy use, depending on the owner's property, habits, knowledge and interests.

Energy is used for space heating, domestic hot water and electricity use. Energy is provided from district heating and radiation through windows and internal gain from human presence. Losses occur through airing and leakages through the house shell.
Indoor temperature is estimated to be 20 ˚C

6.1 Energy use for area B1-detached houses

The total residential energy use of 17 households consists of electricity use and district heating use. Buildings are equipped with energy meters that measure primary electricity use and district heating use.
It would be difficult to estimate energy use of light, appliances, ventilation, etc, because we had only bills for total electricity use.
Since bills from total electricity use were only available data, they are used here to analyze building electricity use. These bills span the dates of March 2012 to November 2013. Bills for electricity and heating in Granåsen were provided on a monthly basis, and they are valuable resurces for analysis of energy use.
Bills for water use were not provided.
Energy use is analyzed in the period from Mart 2012 to Mart 2013.

For the analysis of energy use is used Excel’s Data Analysis Tool, which is good tool for stastical analaysis and presentation of devations from standard values.

6.1.1 Electricity use

The annual electricity use of these investigated households is analyzed in the above way.
Among the 17 families, 3 households had consumption data only for 3 months or 4 months, so that there was no sense to analyze them. Also only 2 families failed to record the monthly amount of energy use in February and 3 families failed to record the monthly amount in July, and 2 families failed to record in October and November. So the respective average monthly amounts of energy use for these months are used to instead of the missing values.

Figure 6-1 shows average monthly electricity use by 14 detached houses.

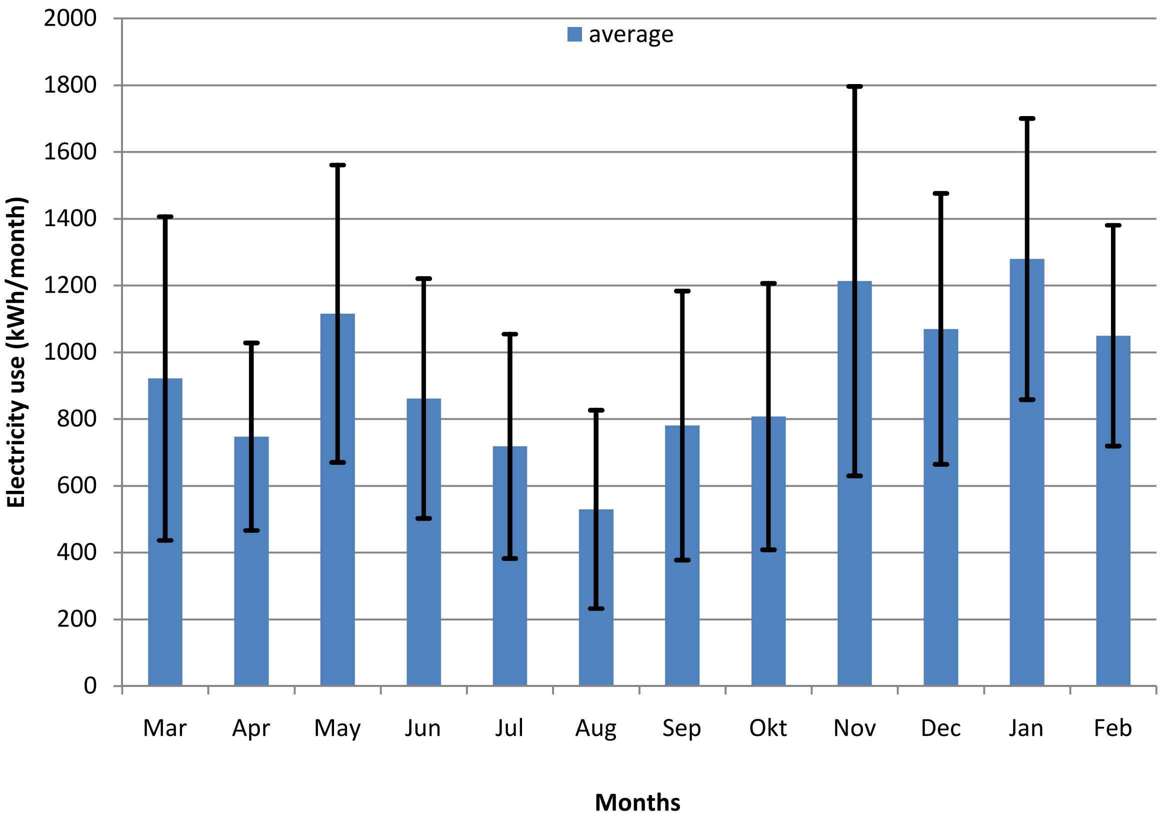


Figure 6-1: Electricity use by 14 detached houses in first 12 months

The average values of monthly electricity use are reflected in Figure 6-1, which also shows other basic statistics such as minimums, maximums, and standard deviations for each household. The standard deviation shows the deviation extent of household energy use from average values.

The standard deviation is largest in November which indicates that this month has the largest difference in electricity use among all the families.

It is found that the quantity of household electricity use is larger in summer and winter than in spring and autumn, and it reaches its max in January and its min in August.

Electricity use in different households varies over month.

Next figure shows average electricity use of the first 12 months in each of 14 detached houses. Naturally some houses use more electricity than others, and this is apparent in the demand data of the 14 analyzed houses, and it is interesting to see the data presented side by side.

The electricity use in house D10 is larger than in the others, with the average value of 1500,05 kWh/month, and the maximum value in of 1989 kWh/month.

House with smallest electricity use is house D2, with average value of 467, 45 kWh/month.

Figure 6-2 shows monthly electricity use in each of 14 detached houses.

This diagram clearly presents that the same type of household have a large variation in monthly energy use.

It is evident that electricity use is dominant during the winter months, two times more than summer electricity use. Such analysis enables identification and recognition of anomalies in energy use.

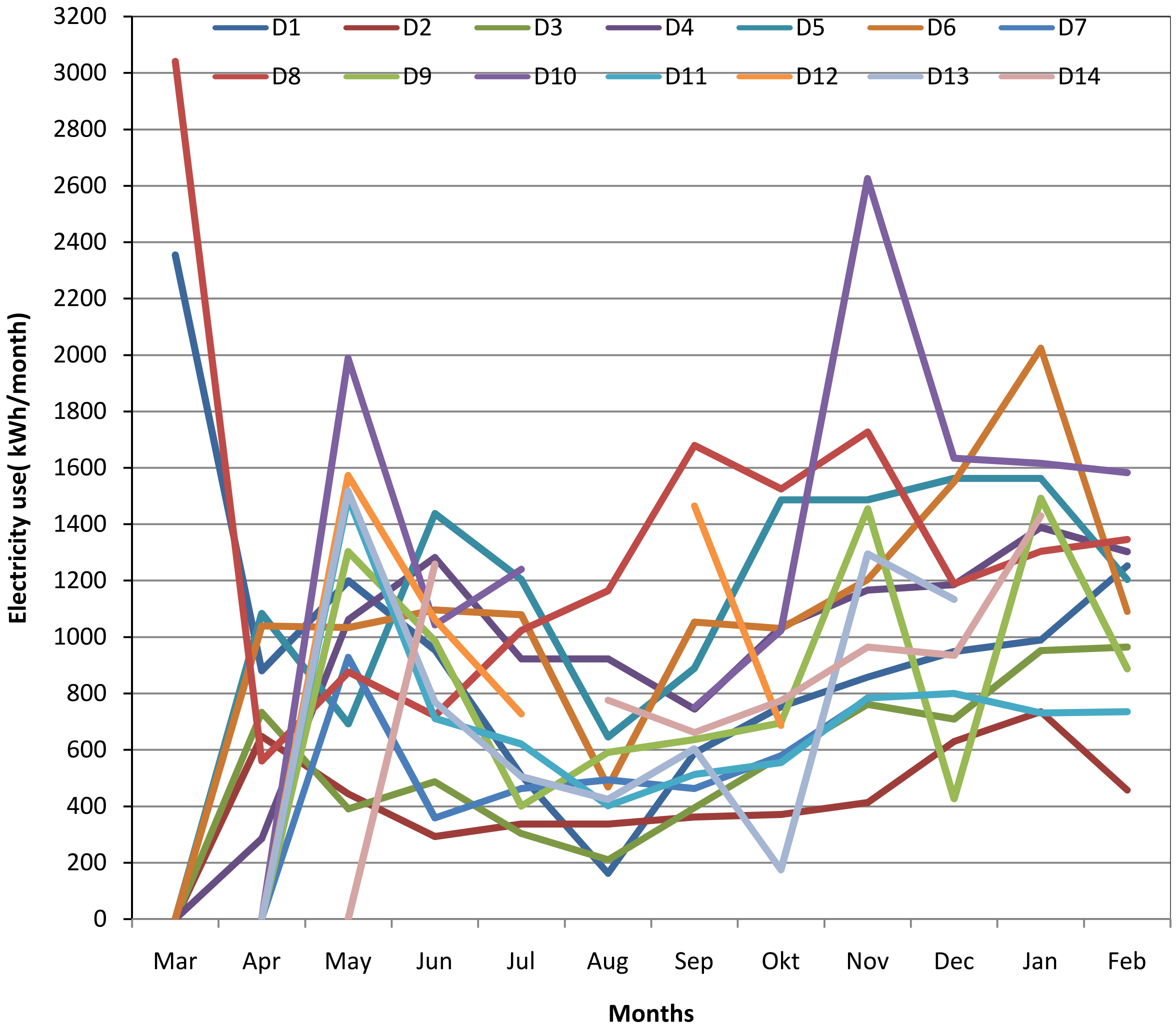


Figure 6-2 Monthly electricity use in each of 14 detached houses

It is obvious that energy use is dependent of outdoor conditions (outdoor temperature) or changes in the regulation of heating systems (indoor temperature), or both.

Average electricity use per month varied between 21 kWh and 3220 kWh per household.

Houses like D4 and D6 have approximately uniform monthly consumption, while others like D8 have a big variation. Reason for higher electricity use in summer can be using of underfloor heating.

In November electricity use in house D8 was 3220 kWh, what is the highest electricity use measured for a single month. Reason for such big electricity use is probably because of the renovation of the house.

6.1.2 Heating energy use

In Norway the heating necessities of buildings are most relevant with respect to energy use as, according to Statistics Norway (SSB), heating is responsible for approximately 50% of the total energy use of a household *(Bøeng and Larsen, 2008).*
Passive houses require less energy for heating and hot water *(Dokka and Hermstad, 2006).*
Heating in each house is based on radiator in every floor, the bathrooms has installed underfloor heating, and heated floor area is about 180 m^2.

Data for heating energy use are available on monthly level from March 2012, the energy for heating is used from district heating, except bathroom underfloor heating, domestic hot water heating is also provided by district heating.

In this work is analyzed heating energy use from March 2012 to February 2013, during this period data for some houses are missing. Figure 6-3 is presents average monthly heating energy use in first year for 14 houses.

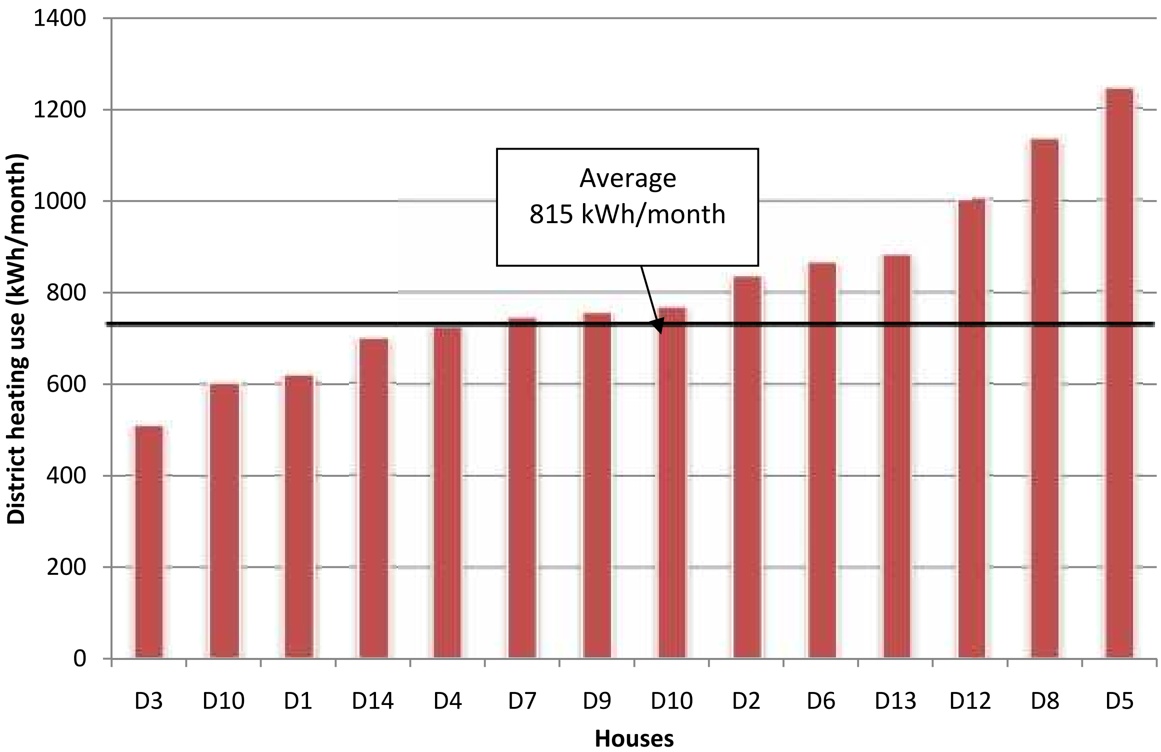


Figure 6-3: Heating energy use in each of 14 detached houses for first year

On diagram, for better view, houses are ranked by energy use from smallest to largest.
Heating energy use varies from 450 kWh/month to 1220 kWh/month.

From the previous image we can see that the average heating energy use is largest in house D5, with the average value of 1245, 41 kWh/ month, and the maximum value of 2211 kWh/month. Possible reason for this is that they have installed additional heating in hall.
House which is the most „energy aware“ is D3 with the average heating energy use of 461,9 kWh/ month.

Outdoor temperature and heating energy use are closely related, when the outdoor temperature is higher, the heating energy use should be lower. The relationship between average monthly energy use and outdoor average temperature is further illustrated in Figure 6-4.

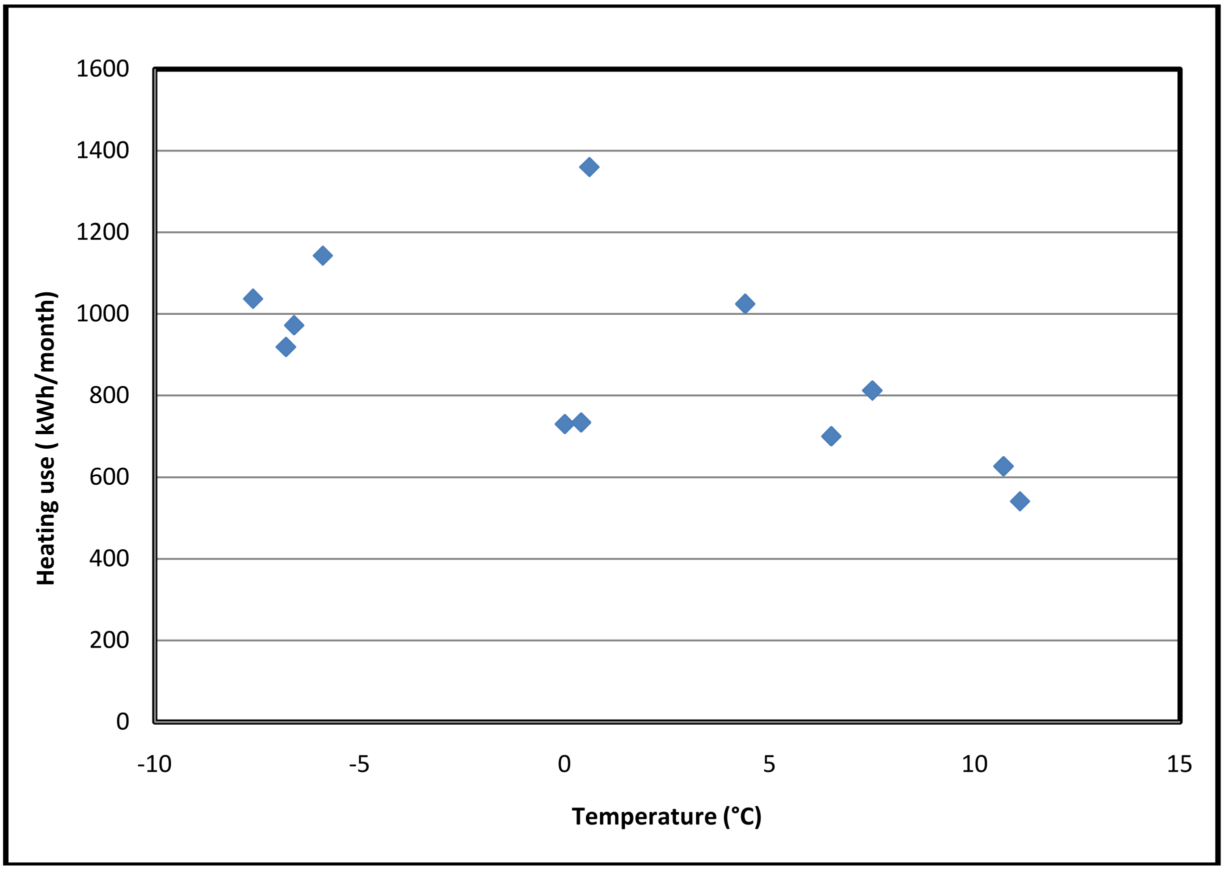


Figure 6-4: Heating demand in the function of outdoor temperature

Figure shows that more heating energy is used due to the lower outdoor temperature. The highest average energy use was in March 2012 year, for temperature 0, 6 °C, with average value of 1359 kWh/month. Heating use was sometimes also high for higher temperatures, like in June last year, for temperature of 7,5 °C, with average value of 812,5 kWh/month.

High heating energy use in the summer months can be a result of simultaneous ventilation and heating of rooms and overheating of rooms.

6.1.3 Specific energy use

In this chapter is presented specific energy use, actually use per square meter of surface of electricity and heating energy.
Electricity-specific use is the part of energy use that can only be covered by electricity, i.e. energy consumption for electrical appliances and lighting.
Specific heating and electricity use per m^2 in first year for 14 houses is shown in Table 6-1.

Table 6-1 Specific energy use in first year for detached houses

Houses	Spec. el. use (kWh/year/m^2)	Spec. heating energy use (kWh/year/m^2)
D1	65,69	46,88
D2	69,69	62,35
D3	55,97	35,55
D4	70,56	59,17
D5	74,18	51,45
D6	86,61	59,86
D7	48,58	55,25
D8	77,49	65,08
D9	53,94	45,47
D10	71,02	35,16
D11	48,47	48,12
D12	59,98	62,23
D13	54,18	57,79
D14	57,06	40,23

We can notice that some homes use far more electricity than the energy for heating, while others use both approximately equally.
The largest consumer of heating energy is the house D8, with specific heating energy use of 65, 08 kWh/m^2 yr.
From the same table we can also see that highest specific electricity use is in the house D6, with value of 86, 61 kWh/m^2yr.
Considering the monthly electricity and heating energy use from the previous analysis, it is clear that the heating energy use is higher than electricity use in winter months.

This gives an average heating energy use per square meter of 52,64 kWh/m^2 yr and 63,81 kWh/m^2 yr for electricity which is slightly different from the recommended energy limits described in the regulations for technical requirements in buildings.

6.2 Energy use issue for area B2

In this area are terraced houses. We analyzed 15 households for that we had complete data about monthly use for electricity and district heating.

For several houses energy use data was missing so they are not analyzed.
Also when families failed to record the monthly amount the overall average value for that months are used to replace the missing values.
In this area houses have been in use since July 2012, and we analyzed them for first 12 months.

6.2.1 Electricity use

Figure 6-5 presents average value of monthly electricity use for chosen households in first 12 months. Standard deviation shows the deviation extent of household energy use from average values.
We could notice that here is situation quite different then in area B1, and that people in this homes spend more electricity in winter and autumn season, then in summer, what is logical.
The standard deviation is largest in April which indicates that in this month is the largest difference in electricity use among all the families.
Household electricity use reaches its max in November and its min in July.
The chart shows that average electricity used for is around 300 kWh in mid-summer (July), but in cold winter month (January) it is up to 900 kWh.

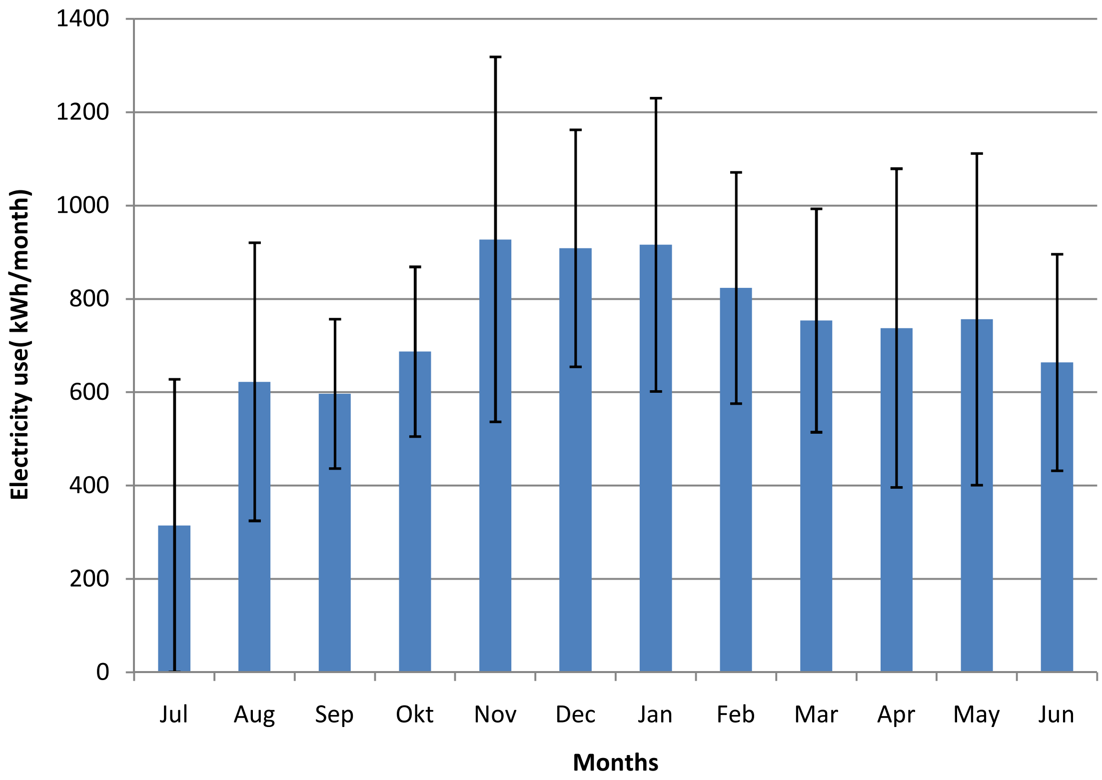


Figure 6-5: Electricity use in first 12 months for area B2

Some households spend more electricity than others, and this is shown on the next figure, where is presented the monthly demand data of each 15 analyzed households.

Fig. 6-6 displays average value of electricity use amounts in each terraced house in the first 12 months of house use. Household have a large variation in monthly energy use.
It is evident that electricity use is dominant during the winter months, two times more than summer electricity use. Increased electricity use during the winter can be explained with the increase of use of lighting, we know that daylight in winter season in Norway is present only for awhile. Over the year, most electricity in Norway is used in winter time.

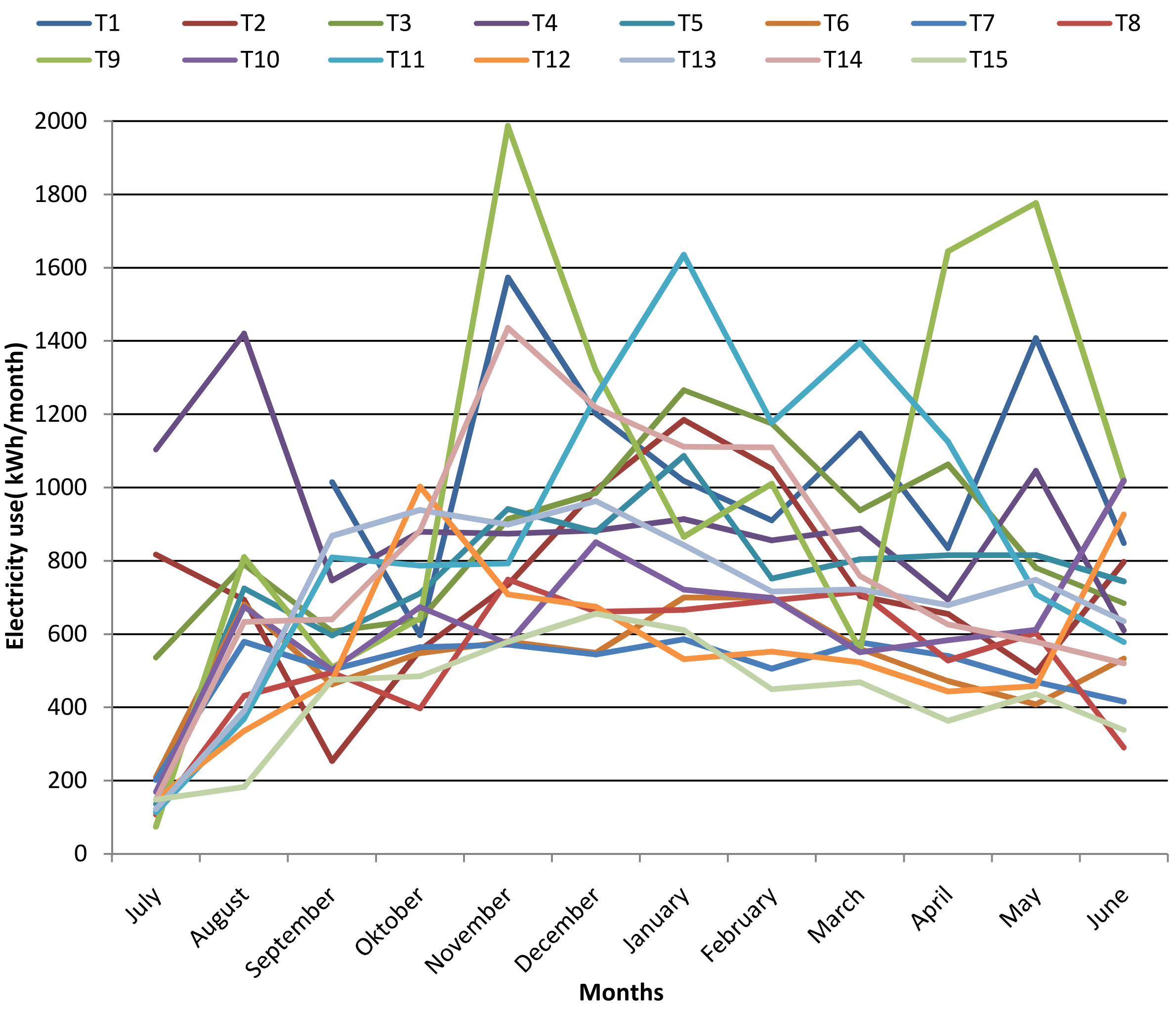


Figure 6-6: Electricity use in first 12 months for each terraced house

Average electricity use per month varied between 74 kWh and 1777 kWh per household.
It is evident that electricity use in house T9 is much larger than in other houses, with the average value of 1017, 83 kWh/ month. One of the largest consumers is also the house T1 with the average value of 1006, 27 kWh/ month.
In November electricity use in house T3 was around 2000 kWh, what is the highest electricity use measured for a single month.

House with the smallest electricity use is T6 average value of 533, 4 kWh/month, what is almost twice lower in comparison with T9.
It is expected that energy use for terraced houses should be less than for detached houses, what is evident.

6.2.2 Heating energy use

The space heating includes radiator heating on each floor and floor heating in the bathrooms, and heated floor area is about 160 m^2.

Data for heating energy use were available on monthly level from July 2012, the energy for heating is used from district heating, domestic hot water heating is also provided with district heating. Heating is necessary in the cold season, which typically lasts from September to May, while minimal amounts of energy are used for space heating in the warm season from May to August. (*Energy consumption 2012*)

Figure 6-7 is presents average monthly heating energy use in first year for 15 terraced houses.

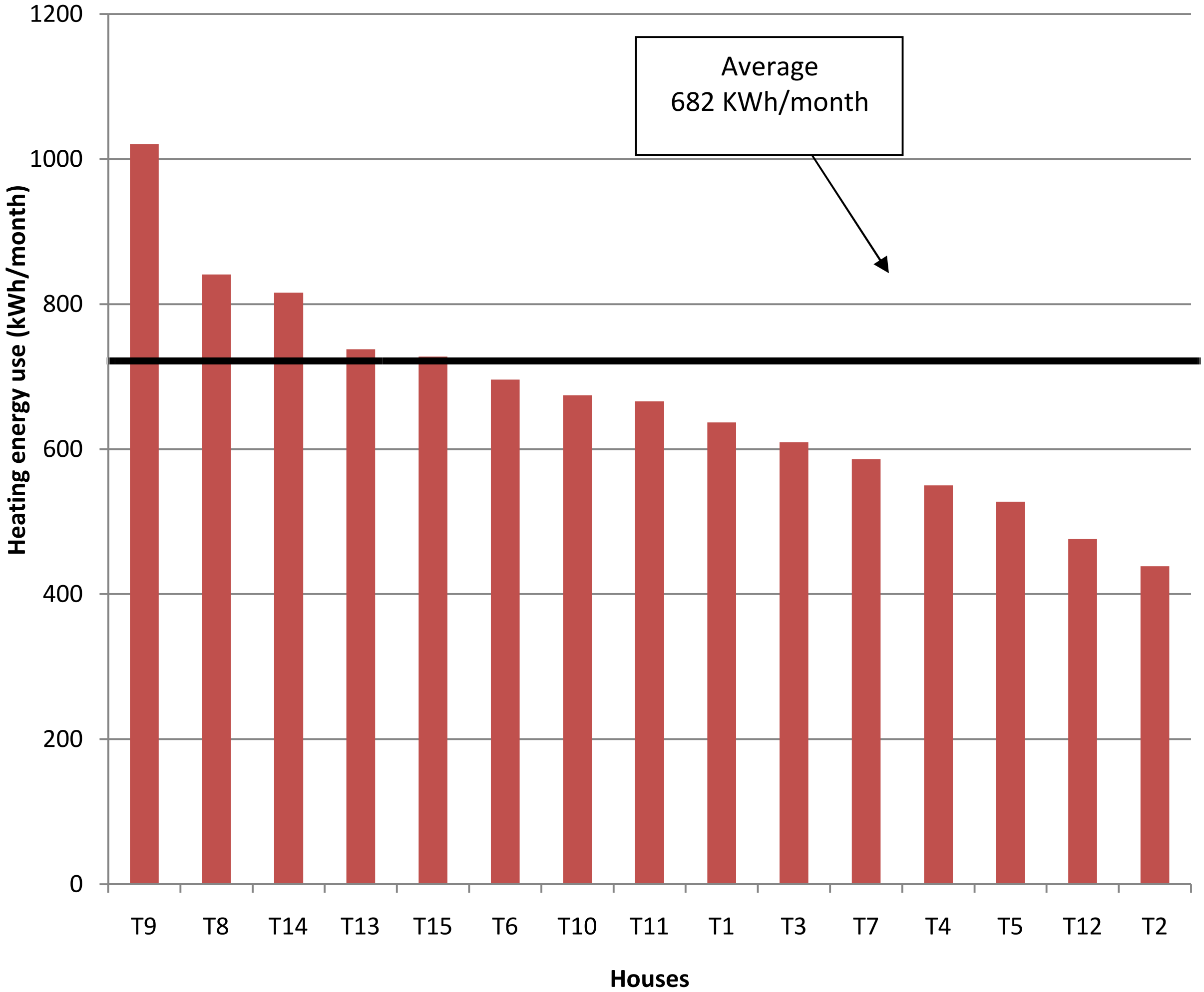


Figure 6-7 Electricity use in each of 15 terraced houses

From previous figure we can see that the average heating energy use is largest in the house T9, with the average value of 1020, 67 kWh/ month, and the maximum value of 2050 kWh/month. We should underline that all houses are the same and it appears that user behavior are essential for energy use. Energy use from the figure is not corrected for temperature and it would be natural to assume that most of the variations in energy use are due to changes in indoor temperature. We can conclude that it is not climatic conditions that determine the heating pattern, but rather the occupants' behavior.
This high heating energy use can be explained by insuficient power of radiator to achieve required temperature.

6.2.3 Specific energy use

Specific heating energy use per m^2 in first year for 15 terraced houses is shown in table 6-2.

Table 6-2 Specific energy use in first year for terraced houses

Houses	Spec. el. use (kWh/year/m^2)	Spec. heating energy use (kWh/year/m^2)
T1	61,89	50,66
T2	57,08	28,48
T3	62,93	46,96
T4	62,66	37,46
T5	50,01	35,73
T6	37,28	56,96
T7	34,18	38,71
T8	56,99	56,54
T9	40,06	41,13
T10	36,63	53,64
T11	61,58	45,9
T12	41,06	33,78
T13	51,66	49,2
T14	58,58	54,97
T15	31,46	50,1

The largest consumer of heating energy is the house T6, with specific heating energy use of 56,96 kWh/ m^2 yr.
In the case of electricity use we can see that the highest specific electricity use is in the house T3 with value of 62,93 kWh/ m^2 year.

It is obvious that most of the houses in this area have a lower specific energy use in comparison with the area B1 due to the lower surfaces of houses.

Table shows that two houses achieved total energy use lower then estimated. But still the majority of houses have increased total energy use in comparison with estimated. Unfortunately, none of the houses did not achieve heating energy use lower that estimated.

Figure 6-8 shows comparison between monthly emectricity and heating energy use for area B2.

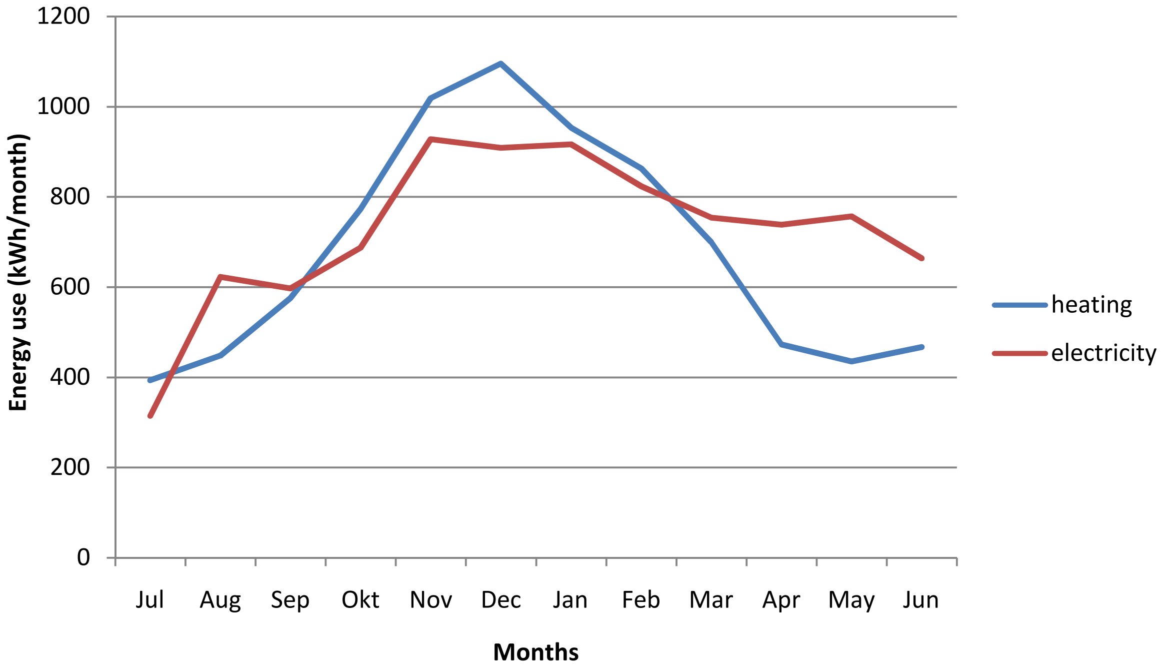


Figure 6-8: Comparison between average monthly electricity and heating energy use for area B2

Considering the monthly electricity and heating energy use from the previous analysis, it is clear that the heating energy use is higher than electricity use in winter months what is shown in previous chart.

We can conclude that relationship between the electricity use and heating energy use during the different seasons depends of the type of the construction, equipment installed in the building and the climate. In the summer season there is decrease of energy use that enables the use of natural ventilation instead of air conditioning.

7. Domestic hot tap water

As we did not have date about hot tap water use, and wanted deeply to analyse it what is presented in this chapter, which consist assumption of domestic hot tap water use in households.
A standardized domestic hot water demand is assumed when calculating the energy use for domestic hot water. The yearly use of domestic hot water, V_w in m^3 is assumed to be 12 m^3 per apartment + 18 m^3 per person.

In detached houses and terraced houses, the use of domestic hot water, V_w is assumed to be 16 m^3 per person.

The energy use for domestic hot water heating is assumed to be 55 kWh/m^3 which means that the total energy demand for domestic hot water, E_w is:

$$E_{VV} = \frac{55 \cdot V_{VV}}{A_{temp}} \text{ (kWh/m}^2\text{a)} \quad (1)$$

A_{temp}- Heated area

Table 7-1 presents number of persons in apartments based on the number of rooms

Table 7-1 Number of persons assumed in apartments as a basis for calculating the energy use for domestic hot water

Number of rooms	Number of occupants
1 room and a kitchen	1.0
2 rooms and a kitchen	1.5
3 rooms and a kitchen	2.0
4 rooms and a kitchen	3.0
5 rooms and a kitchen	3.5

For detached single-family houses, three persons are assumed when the house is smaller than 120 m^2 and four persons are assumed when the house is larger than 120 m^2.
(Passive houses in Sweden)

7.1 Calculated domestic hot tap water for areas B1 and B2

The domestic hot tap water is supplied by the district heating.
The most useful factor to predict hot water use is the number of occupants in the dwelling. Figure 7-1 shows the variation in energy use as a function of occupancy. It is showen linear increase in hot water use with increase of number of occupants.

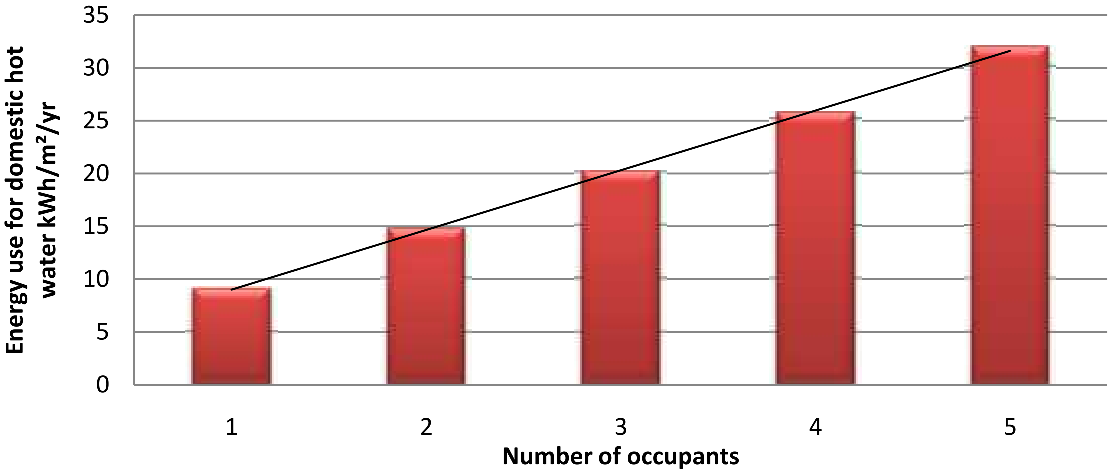


Figure 7-1: Hot water consumption as a function of occupancy

Based on the number of rooms in houses number of occupants is assumed and in that way is calculated annual use of domestic hot water. The Figure 7-2 presents the obtained results.

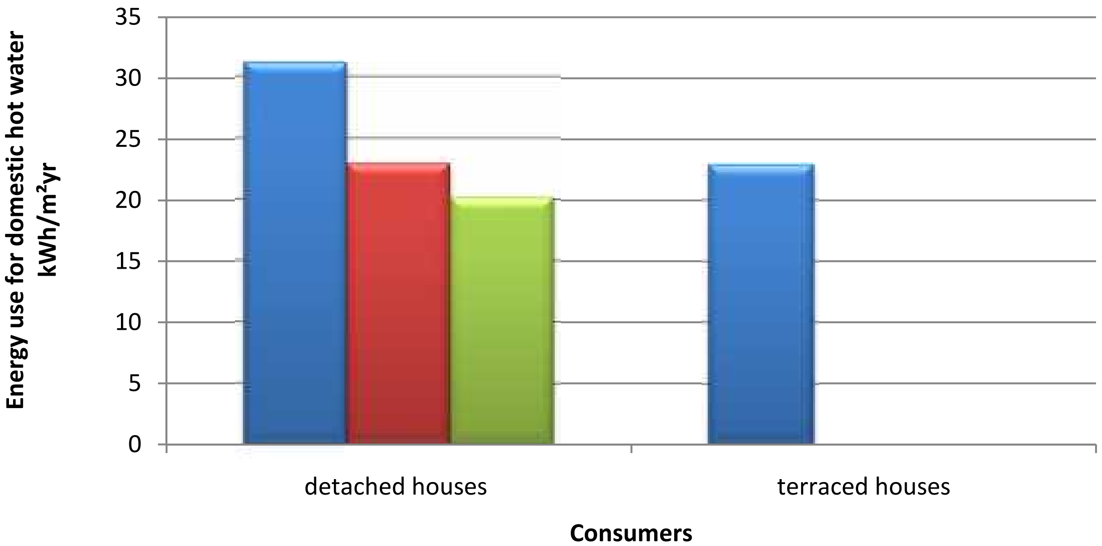


Figure 7-2: Annual energy use for domestic hot water by consumers

The highest domestic hot water use is in some of detached houses because they have the greatest number of rooms: kitchen + 5 rooms. Terraced houses have a lower use of hot water, because they have and lower area for 20 m².

8. Domestic electricity use by end-users

As we did not have any information about installed devices in households and in order to deeply analyze energy use for different end users we identified energy use for detached and terraced houses.
It is difficult to estimate which appliances were installed in homes, but it could be asumed that the use typical home equipment.
Electricity use in an individual dwelling is dependent upon the activities of the occupants and their use of electrical appliances.

In this chapter through the simulation of appliance use electricity demand data is created, which covers appliances that is commonly found in the households today.
The appliances in the model are configured with their mean total month energy demand and power use characteristics.
It is important to create a relationship between energy use and occupant activity.
Number of occupants and their activity significantly affect on consumption, we can see that from the Figure 8-1.

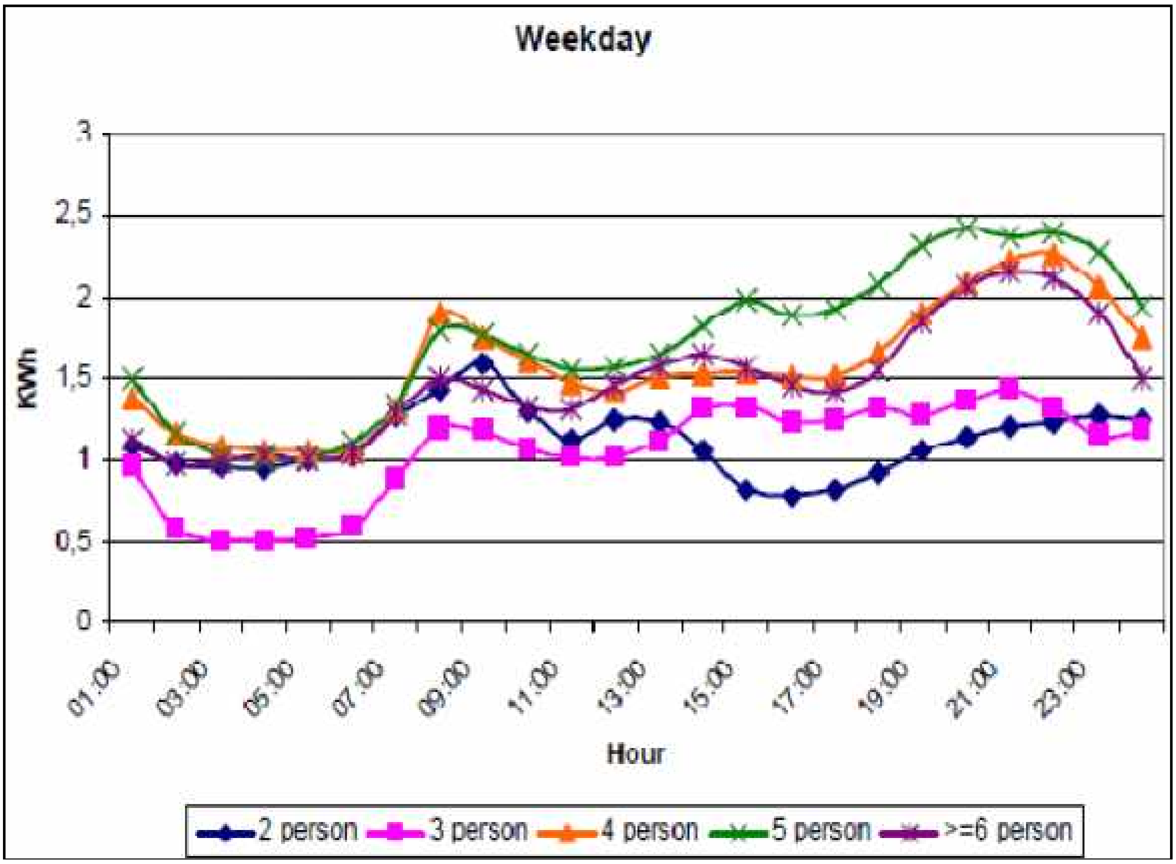


Figure 8-1: Daily consumption based on occupant's number during weekdays *(User behavior and patterns of electricity use for energy saving)*

Modeling was performed in the following way:

- The activity profile is chosen according to the appliance activity, the current number of active occupants

  Some appliances do not depend on active occupancy. Appliances such as a fridge or freezer, does not depend on people being active.

- Electricity use for each appliances is obtained with power of appliances and its operation time

Next figure shows simulated active occupancy for the households throughout the day.
In our example simulation the household has four residents, but three are active at any one time.

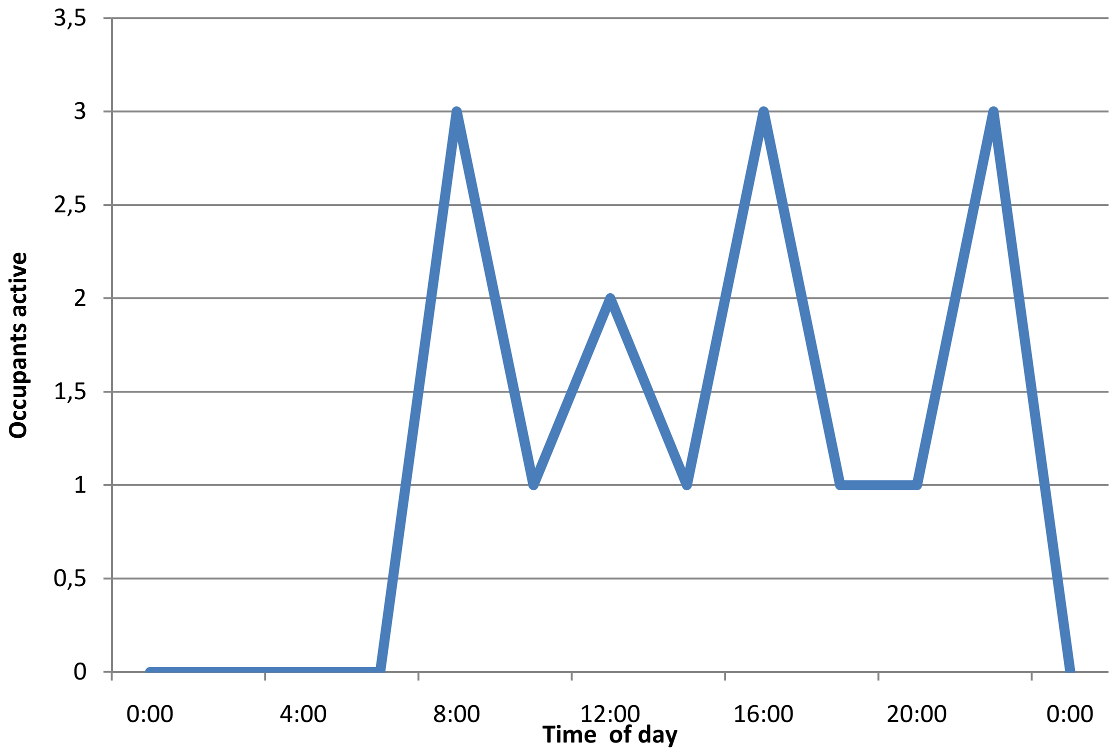


Figure 8-2: Household active occupancy profile

8.1 Electricity use by end-users for detached houses

Because data about electricity use by appliances were not available, and we wanted to analyze it deeply in this chapter is used calibration method for modeling of electricity use.
For the household, occupants have the right to decide if they want to use energy efficient appliances or not.

SINTEF Energi is chairing a research project called **ElDeK8** (SINTEF), which is metering electricity consumption in households. The results from this study are provisional and limited primarily to detached houses with electric heating. Their research shows that about 2,000 kWh is used for lighting and about 3,600 kWh for electricity-specific consumption. Electricity consumption for electricity-specific end-uses therefore comes to about 5,600 kWh/ yr. The study also shows that about 2,300 kWh is used for water heating. *(Energy consumption 2012 Household energy consumption)*

Each appliance has a "calibration scalar" which is described into the probability of switch-on.
For analysis is considered typical appliances in households with their power. It is also taken in consideration standby power consumption, which also has important impact in electricity use. Underfloor heating in bathroom and WC, is included in electricity use. For each house is analyzed electricity use in months when consumption was the largest.

This formula is used to estimate an appliance's energy:

(Wattage × Hours Used per month ÷ 1000 = Monthly Kilowatt-hour (kWh) consumption
(1 kilowatt (kW) = 1,000 Watts). *(Appliance Energy Use and Costs in Alaska)*

Below is shown example of two houses, with different electricity use. One consumes a lot of electricity, and the other has more efficient electricity use.

Table 8-1 presents electricity use for house D5.

Table 8-1 Energy use by end-users for house D5

Household users	Maximum power (W)	Standby power (W)	Average use per month (h)	Time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
plasma television	300	3	180	540	5,5
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster &broiler/oven	600		6		3,6
Tumble drier	1200		15		18
Clothes washer	512		9		4,608
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		400		488
Lighting	2000		360		720
Σ					**1727,13045**

First house is D5, with larger electricity use. Observed month is January, and measured electricity use is 1727 kW.

Modeled usage of 22 users through month is shown in previous table. The television, DVD, PC are used more through period, while microwave, oven and small appliances are used less. Lighting usage is considered for winter time.

Table 8-2 shows house D2 which is more „energy aware". Observed month is January, and measured electricity use is 735 kW.

Table 8-2 Energy use by end-users for house D2

Household users	Maximum power (W)	Standby power (W)	Average use per month (h)	Time in standbye (h)	Monthly Avg Use kWh
Plasma television	180	3	120	400	22,8
DVD player	40	3	120	540	6,6
Laptop	50	10	192	400	13,6
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Dishwasher	1050		20		21
Hair Dryer	750		5		3,75
Toaster & broiler/oven	600		5		3
Tumble drier	2000		10		20
Clothes washer	300		10		3
Electric Oven	1100		15		16,5
Juicer	90		1		0,09
Mixer	80		1		0,08
Shaver	15		3		0,045
Underfloorheating wc and bathroom	900		234		210,6
Lighting	900		205		184,5
Σ					**734,965**

From these two examples we can notice how big influence on electricity use can have time of appliances use, and installed power. These two houses have the same surface and structure, but first spend two times more energy.

Disregarding energy use for underfloor heating, the fridge uses the most energy in this case. The fridge uses about 6 percent of the annual average electricity use.

Reason for such a low electricity use in other house, could be that people were absent for a while, or maybe only one or two occupants were present in the house for that period.

This model is based on prediction of energy use between households when there is no active occupants, only the fridge could used electricity.

It is important to underline that this model was constructed entirely without any information about installed appliances in households.

Figure 8-3 shows how much electricity a typical appliance uses per month.

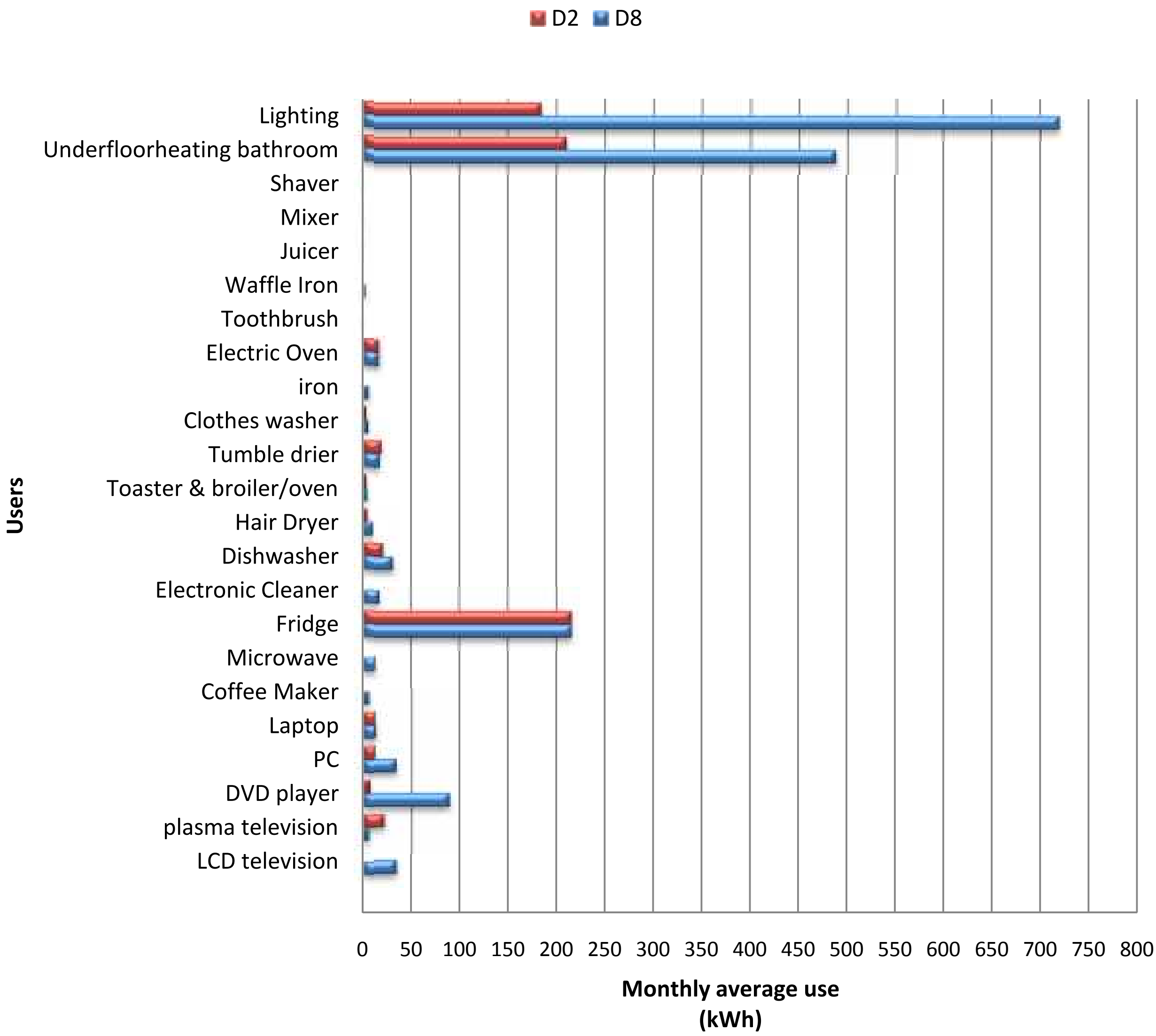


Figure 8-3 : Distribution of energy used by appliances for two detached houses

For example, a fridge uses almost five times more the electricity then television, because it is turn on all the time.

Appliances like television, PC are used for relatively long periods throughout the day, while small appliances like iron are used for much shorter periods. The washing machine is used 4 times per week.

Children, perhaps particularly families with babies tend to consume more electric energy than, for example pensioners and families without children.

One average, households with children living at home consume twice as much electricity for this purpose than households without children living at home *(Energy consumption 2012 Household energy consumption).*

8.2 Electricity use by end-users for terraced houses

First house is T3 with measured electricity use of 1266 kW in January 2013. Modeled electricity use is shown in Table 8-3.

Table 8-3 Energy use for appliances for house T3

Household apliances	Maximum power (W)	Standby power	Average use per month (h)	Time in standbye	Monthly Avg kWh Use
Plasma television	180	3	120	400	22,8
DVD player	40	3	120	540	6,6
Laptop	50	10	192	400	13,6
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Dishwasher	1050		20		21
Hair Dryer	750		5		3,75
Toaster & broiler/oven	600		5		3
Tumble drier	2000		10		20
Clothes washer	300		10		3
Electric Oven	1100		15		16,5
Juicer	90		1		0,09
Mixer	80		1		0,08
Shaver	15		3		0,045
Underfloorheating wc and bathroom	900		450		405
Lighting	900		400		360
Central Vacuum System	1500		8		12
Heating cable in hall	500		300		150
Σ					**1266,865**

Consumption of each appliance will vary with usage patterns, but it also depends on how much energy the appliance use (kWh/n, where n is the number of times). We can see this by comparing the energy use of a washing machine and clothes dryer. These are used, on average, an equal number of times during a period (3 times per week)]. This means that a washing machine consumes about 0.3 kWh per wash while a dryer consumes about 2 kWh per dry.
For this house we have information about installed additional heating cable in hall and central vacuum system and that is probably reason for such larger electricity use.

Other possible reasons for the high electricity use are:

- Use of lighting in rooms that normally are not being used
- Use of large electrical consumers that are rarely used

In this case is necessary training of occupants whose behavior affects energy use. Unnecessary energy loss with little effort can be easily avoided.

Table 8-4 shows modeled energy use for house is T15 with measured electricity use of 656 kW for the same month.

Table 8-4 Energy use for appliances for house T15

Household apliances	Maximum power (W)	Standby power (W)	Average use per month (h)	Time in standbye (h)	Monthly Avg Use kWh
plasma television	180	3	80	400	15,6
DVD player	40	3	120	540	6,6
Laptop	50	10	192	200	11,6
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Dishwasher	1050		15		15,75
Hair Dryer	750		5		3,75
Toaster & broiler/oven	600		5		3
Tumble drier	1800		10		18
Clothes washer	300		10		3
Electric Oven	1100		8		8,8
Juicer	90		1		0,09
Mixer	80		1		0,08
Shaver	15		3		0,045
Underfloorheating wc and bathroom	500		320		160
Lighting	600		300		180
					655,715

Occupants in this house are definitely more energy efficient, and likely they installed efficient appliances and turn them off when they do not need it.
There is a possibility that this occupants were away for a considerable amount of time, what resulted in a low level energy use. This could be house with only one occupant.

Only few households have aditional electric heaters installed but those that do, have significantly higher electricity use.

Figure 8-4 shows electricity use by typical appliance per month for terraced houses.

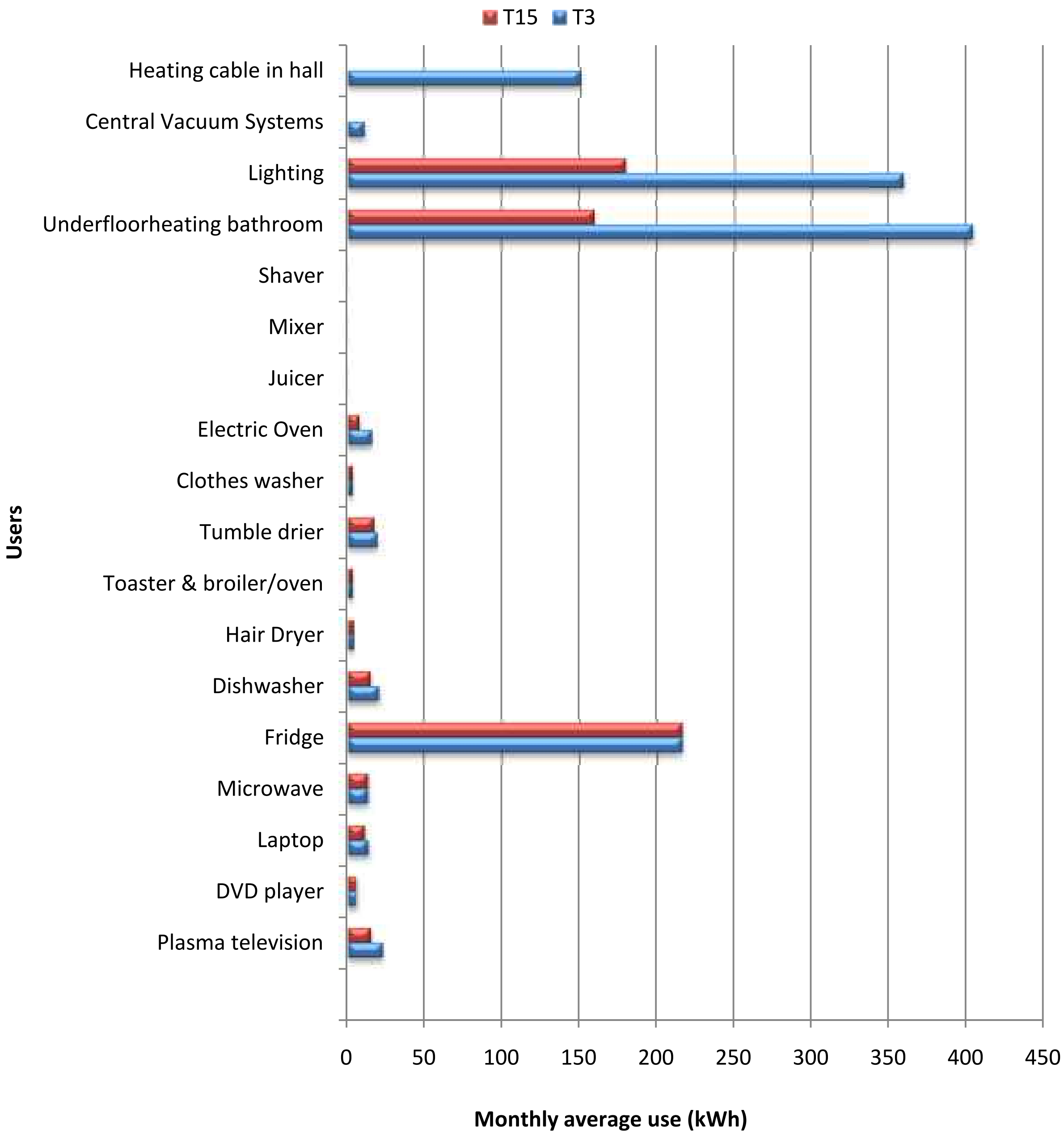


Figure 8-4 Distribution of energy used by appliances for two terraced houses

Previous chart shows distribution of electricity used by appliances for both terraced houses. It is obvious that in house T15 is considerably lower usage of electricity for major of appliances, except fridge which probably use the same amount of electricity.
In both cases majority of electricity is spent for lighting, because people stay in more during winter, due to short duration of the day. This model would be more representative if it could be supported by real measured data.
Results for the rest of the houses are presented in appendix.

9. Radiator heating effect

As we did not have information about effect of the radiator, and wanted more closely to determine it's effect and impact on ambient conditions in this chapter is analyzed heating effect of radiator and its ability to achieve the desired temperature of 20 ˚C. (http://www.purmo.com/fi)

9.1 Heat output calculation model

According to DIN 4703-3 heat output of radiator (W/m) is calculated on this way:

$$\Phi = \Phi_n \cdot \frac{\Delta T}{\Delta T_n}^{n} \qquad (2)$$

In which:

Φ=output, W/m

Φ_n=norm output, W/m-EN 442 when logarithimc ecxess temperature ΔT_n = 49,83 K

ΔT= logarithmic excess temperature, K

ΔT_n= norm excess temperature =49, 83 K

n=temperature exponent

$$\Delta T = \frac{t_{in}-t_{out}}{ln \quad t_{in}-t_{room} \;/\; t_{out}-t_{room}} \qquad (3)$$

t_{in}= flow water,˚C

t_{out}= return water, ˚C

t_{room}= room temperature, ˚C

Based on values:

Φ_n=4000 W/m -estimated according to the size of the radiator

t_{in}= 75 ˚C=348 K

t_{out}= 65 ˚C=338 K

t_{room}=20 ˚C=293 K

ΔT=47,62 K

$= 3767,41\ W/m$ -heat output of the radiator *(http://www.purmo.com/fi)*

9.2 Modeling of effect of the radiator on ambient conditions and heat distribution

In this part is investigated the heating effect of radiator, in order to determine is it possible only with one radiator on the floor to achieve thermal comfort in the house.
Modeling was focused on one floor with one radiator and its position. It is observed distance from radiator to the living room window which is 6, 2 meters. Behind the radiator is bathroom, where is installed underfloor heating. Designed U values for windows, walls, roof and floor are inserted in to simulation. Outdoor temperature was set to 4, 9 ˚C-mean annual temperature for Trondheim. For these two models, average temperature and heat flux of radiator were compared.
Two different values of power density of radiator were considered. For simulation is used simulation program *Energy2D*, developed by Concord Consortium. With this tool it is possible to perform energy audit of object. Thermometers were set up on several places to measure ambient temperature.

For the first model is taken radiator with length of 1 meter, and height of 0,5 meter, power density of 5,5 W/m^3, specific heat is 500 J/kg K are constant.
Results of first model are presented on the Figure 9-1.

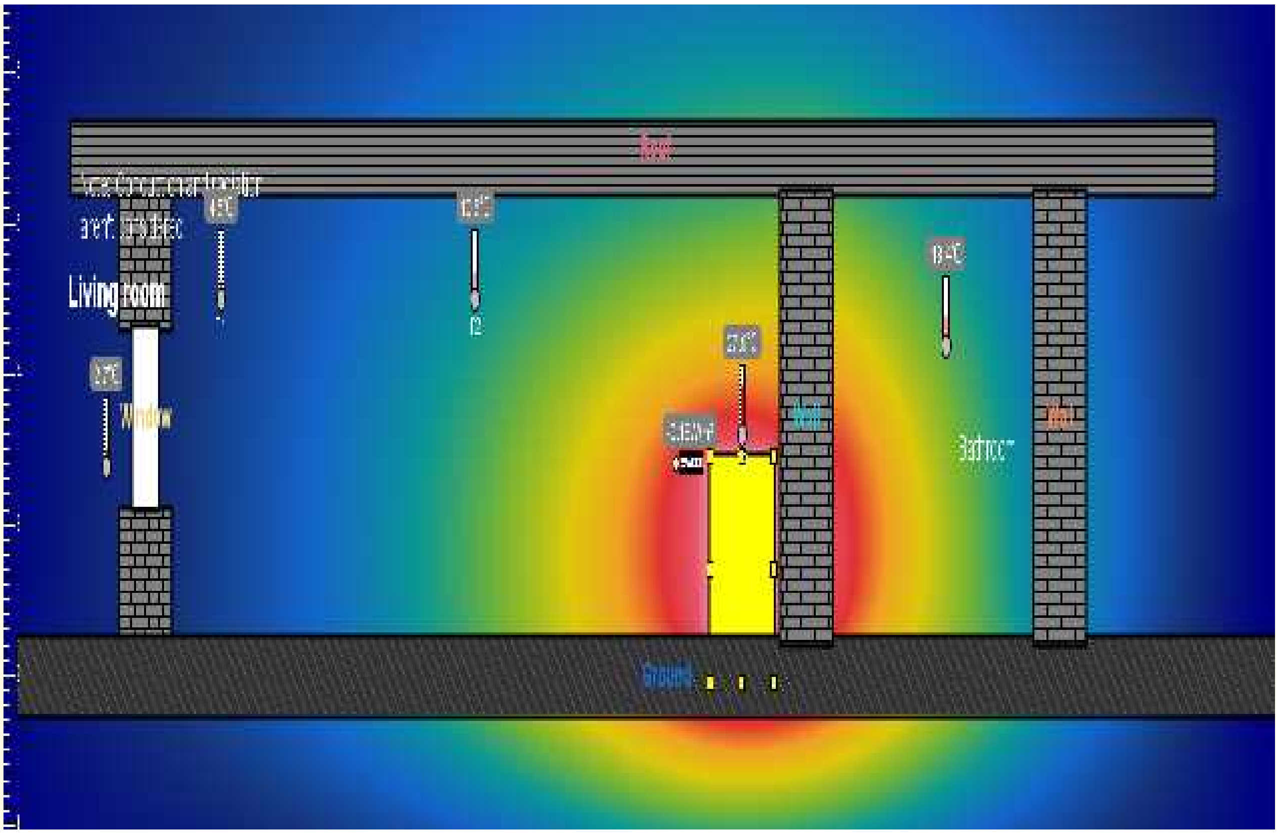


Figure 9-1: Heating model with power density of 5, 5 W/m^3

Results showed that with this thermal characteristics of radiator, temperature just above the radiator is 27.9 ˚ C but in the living room is the super cooling, and the temperature near the window is only 4.5˚C, which creates a feeling of heat inconvenience.

Figure 9-2 presents results for the second model.
In this case power density was increased on 18 W/m^3, and other characteristics are the same like in the previous case.

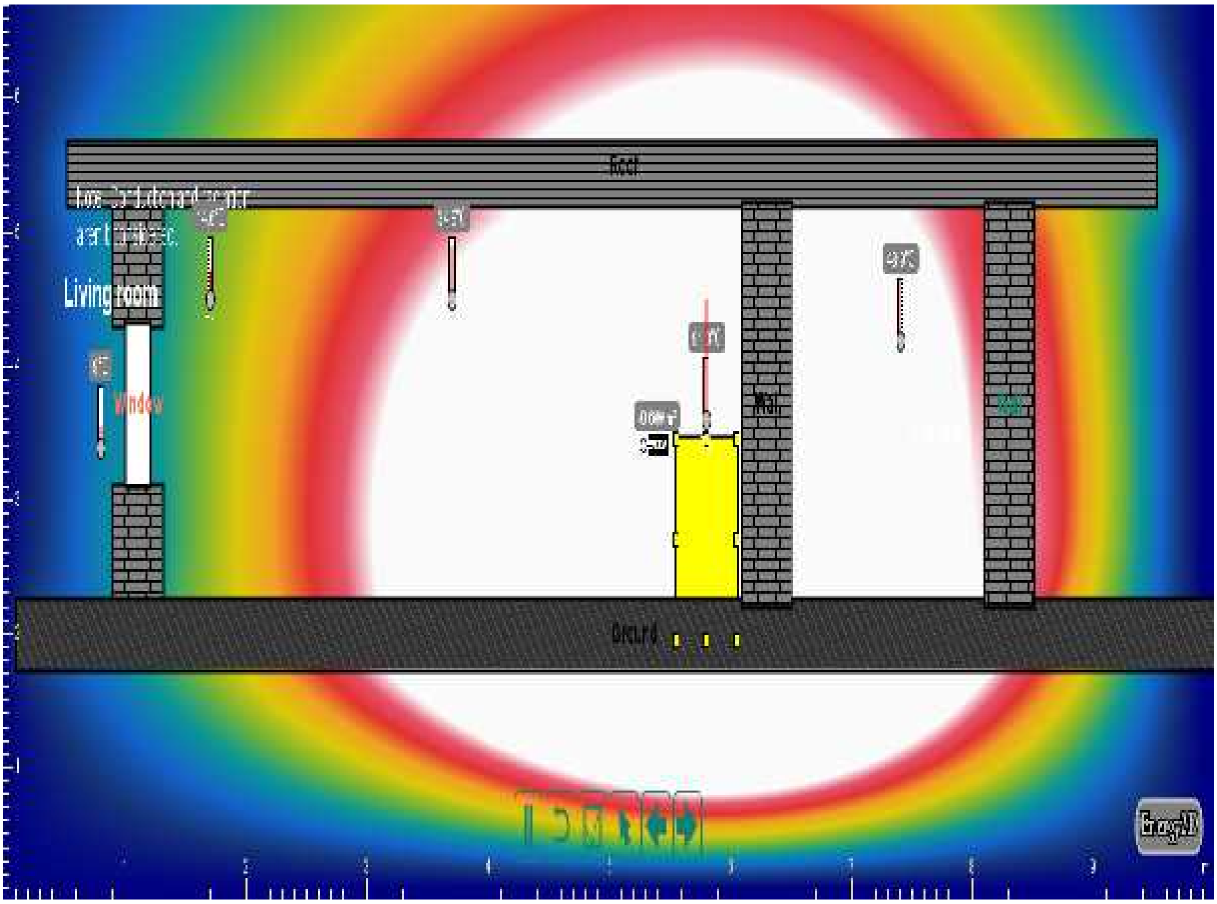


Figure 9-2 Heating model with power density of 18 W/m^3

In this model temperature around radiator is very high 91, 3 ˚C, which would be intolerably, but temperature inside the room, next to window again is not desired 20˚ C.

Conclusions of this simulation are that with only one radiator on the floor can not be achieved desired temperature and occurs the phenomenon of super cooling on what the occupants in these houses complains. So in order to have an optimized temperature distribution more attention must be considered about the placement of radiator in the house. It would be better to have two smaller radiators placed on different sides instead of the big one, and to install them near the windows.

10. Comparison of expected and measured energy

All houses are built under passive house standard, what means that they should meet passive house criteria, but through this analysis is shown that they did not.

The expected energy data were available for area B1 and B2.
For B1 the total energy is simulated to be 86,2 kWh/m^{2}yr, and for B2 74,9 kWh/m^2 yr. This is expected annual energy use but the real situation is different what is shown on Figure 10-1.

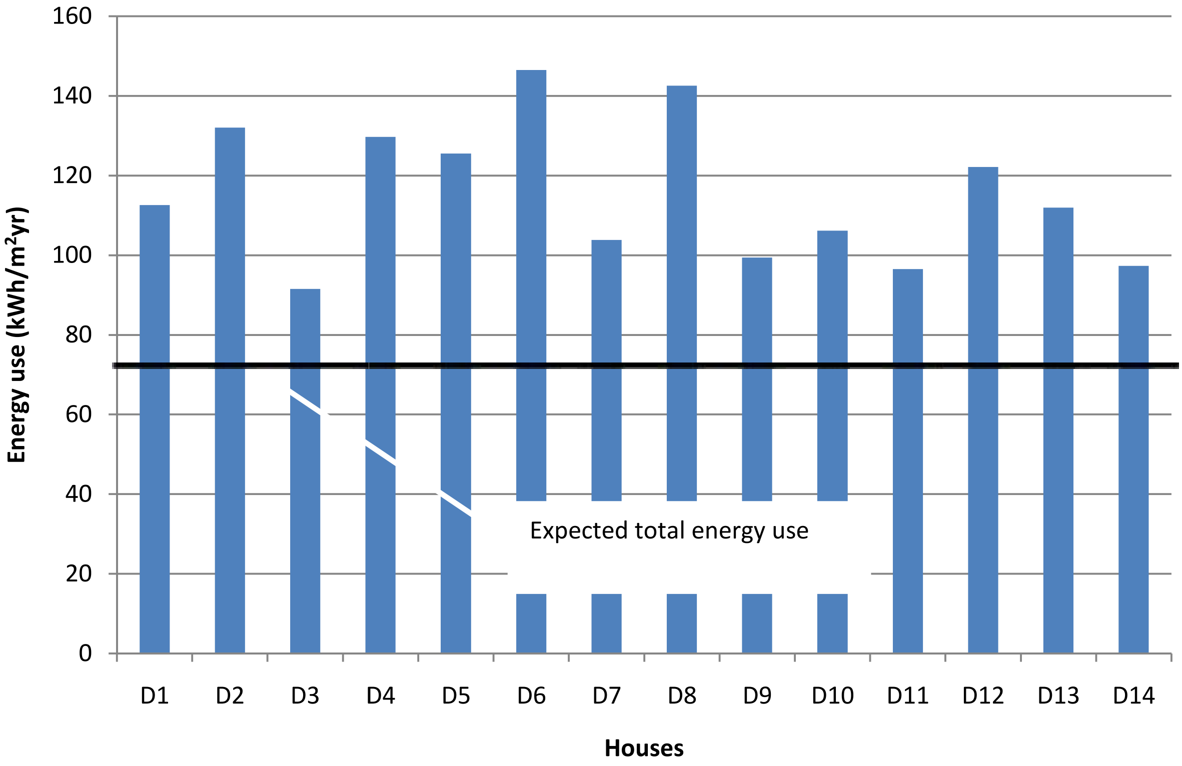


Figure 10-1 Expected and measured total energy use for detached houses

The first chart refers to the area B1. The actual total kWh/m^{2}yr use is consistently higher than the expected total energy use. Any of the houses in this area has not achieved the expected energy use. Expected energy use can not be the same for all houses, and can not be the same for every year, because it depends on many factors, outdoor temperature, occupancy level, their behavior, installed appliances, etc.
From the chart we can see that for the house D6 measured total energy use is about twice the estimated energy for this house. Installed additional underfloor heating in laundry, and heating cables in hall can explain this situation.

Figure 10-2 shows comparison between measured and expected heating energy use.

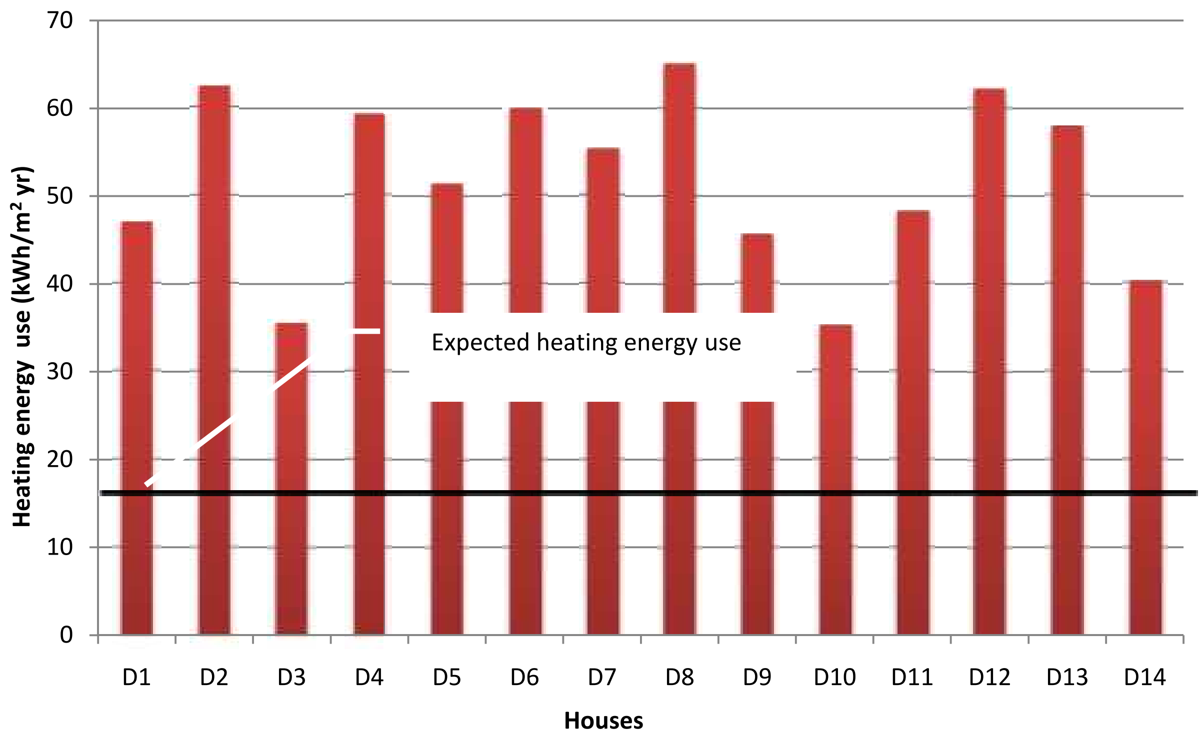


Figure 10-2: Expected and measured heating energy use for detached houses

For area B1 expected annual heating use is 20, 2 kWh/m^{2}yr.
All the analyzed households demonstrated an increase in heating use.
The results of the analysis show that the difference between expected and measured heating energy use in most cases is higher than 100 %. In the house D8 difference between expected and measured heating use is 44, 8 kWh/m^{2}yr. House with the lowest heating energy use is D3 but still with difference between expected and measured heating use of 15 kWh/m^{2}yr.
None of the houses achieved expected criteria for heating energy use.
It is shown that in expected energy use is a tendency trend and which can be achieved with good energy management.

Figure 10-3 shows results for total energy use for area B2.

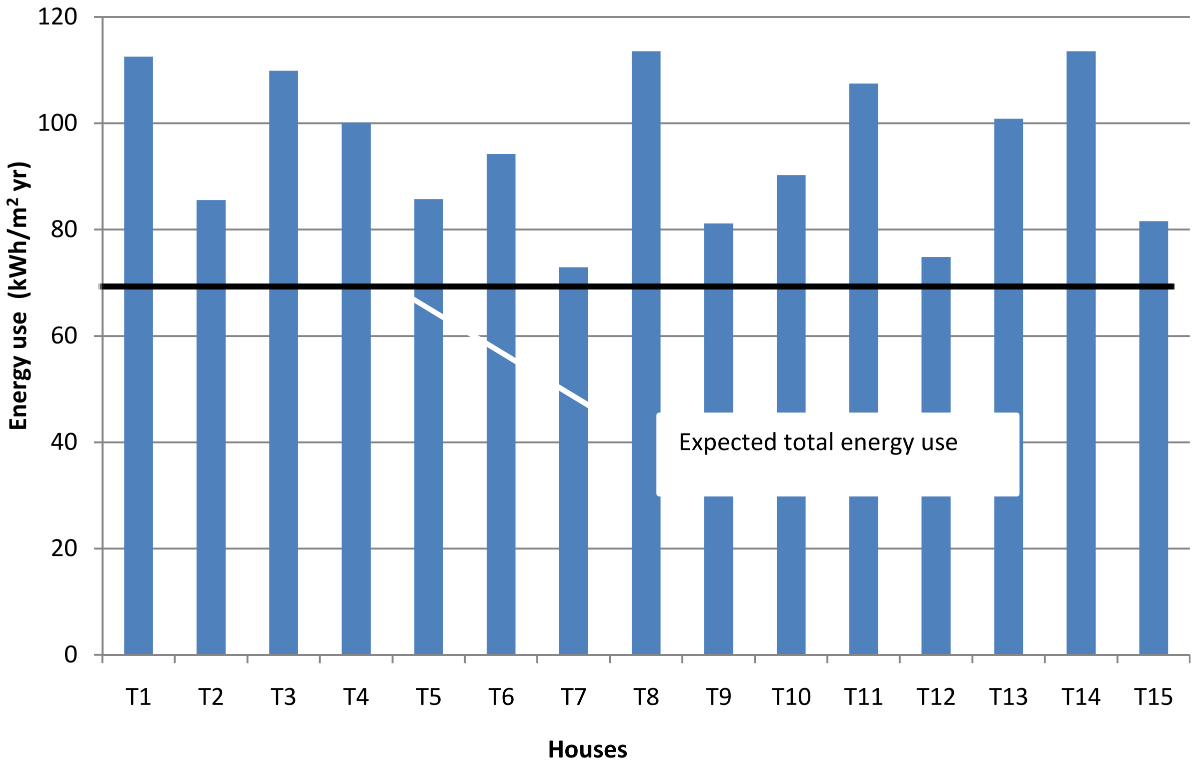


Figure 10-3: Expected and measured total energy use for terraced houses

Here in 2 houses annual total energy use is lower than expected, in houses T7 with difference of 2 kWh/m^2 and T12 with difference of 0,5 kWh/m^2. That means that occupants in this homes are more energy efficient than the others.
On house T7 is placed solar shading which could be one of the reasons for this energy savings.

In all other houses energy use is higher than expected, but not that much like in first area.
In this case house with the largest difference between measured and expected is T8 with difference of 38, 66 kWh/m^2. Reason for this is probably installed central vacuum system and ventilation for bathroom.

This illustrates that buildings with less than 74, 9 kWh / m^2yr or 86,2 kWh/m^2yr estimated energy use, is achieving overall a higher energy use compared with estimated.
In general, there is great variation in the extent of achieved energy use. Total achieved savings are lower than expected for 27 of 29 houses.
There are still large differences between expected and measured energy it that can not be explained by the parameters used in this report, without realistic data.

Figure 10-4 shows comparison between expected and measured heating use for terraced houses.

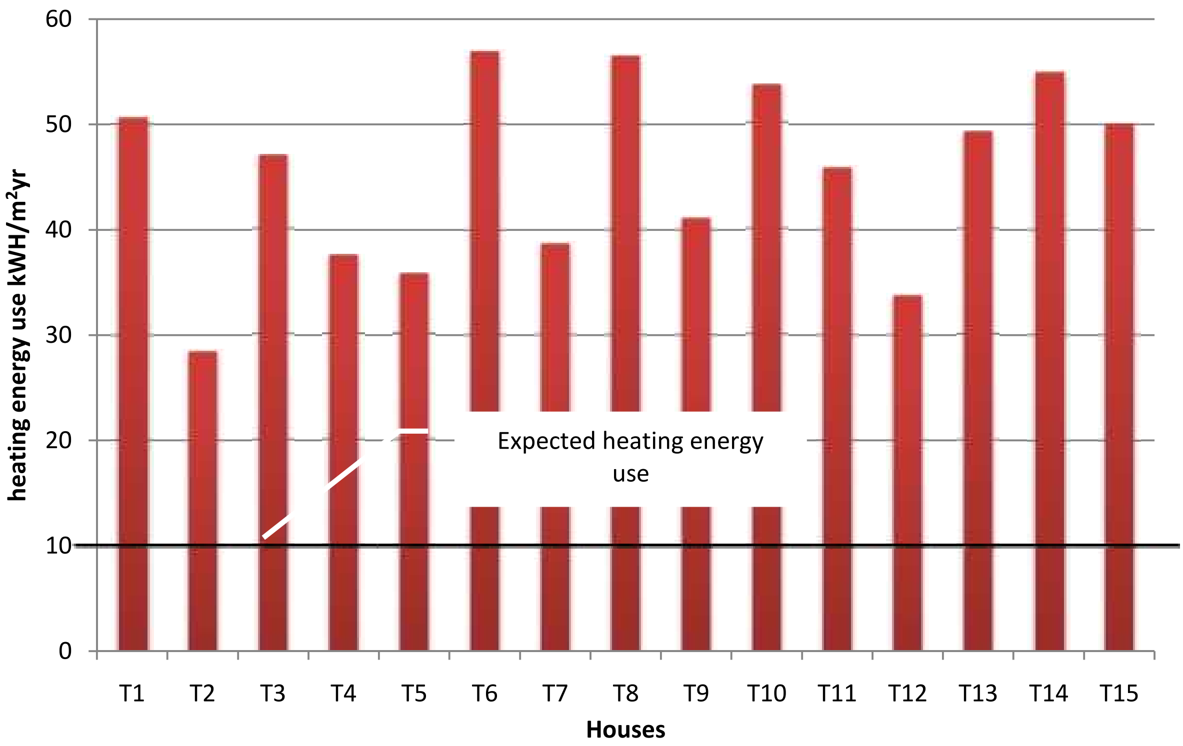


Figure 10-4: Expected and measured heating energy use for terraced houses

For area B2 expected annual heating use is 11, 6 kWh/m^2 yr, significantly lower than in B1, due the lower hating surface.

The biggest differences between expected and measured are in the space heating and the most notable reasons could be that the indoor temperature is turned out to be higher than estimated. It is hard to predict the habits of the occupants and it is difficult to avoid the variation of indoor temperature between houses.

From analysis is shown that houses did not achieve heating use lower than expected.
The largest difference between measured and expected is T1 with difference of 50,29 kWh/m^2 yr.

If there is an increase in energy use compared to the expected, should check next:

- number of occupants
- increasing in installed appliances (p. ex. additional ventilation, heating system)

If changes are short-term, they can be exempted from the analysis. But if they are long-term, it should re-collect all relevant data and define again the expected energy use and relevant goals.

11. Conclusions

Energy use investigations were carried on in ecological city Granåsen for two different house areas, in the first 12 months of their use.

Houses in green city Granåsen did not meet the passive house criteria.
Space heating requirement < 20, 2 kWh/m²yr and 11, 6 kWh/m²yr is not reached for all houses.
Total energy requirement < 86, 2 kWh/m²yr is not reached in detached houses, and energy requirement <74, 9 kWh/m²yr is reached only in two terraced houses.

Unrealistic assumptions in human behavior have a big impact, that is why the energy used for heating was underestimated.

These results should be indicator for users that they should change their behavior.
Users who do not have an 'energy-aware' behavior should also be able to live in passive houses without limiting their activity. Most important, personal comfort should never be restricted, otherwise passive house concept would never be successful.

To achieve the passive house standards, conventional central heating system is not necessary, heating should be provided through the low-volume heat recovery ventilation, air-heating elements can be heated by a heat pump, solar energy, etc.

In the paper is shown that average annual total electricity use for all household is about 115 kWh /m²yr.
Most existing houses in Norway use approximately 130 kWh/ m²yr (*Dokka & Hermstad, 2006).*

It is shows that there is a wide spread in the amount of electricity that households use.
Energy consumption in two identical houses of exactly the same quality may therefore be very different *(Xrgia, 2011).*

Some of them use little kWh/m²yr, while others use about 146 kWh/m²yr.
Largest electricity use for detached houses is in the D6 and reason for that: installed additional underfloor heating in toilet and in the bathroom, and ventilation in bathroom.

It should be underlined that this is a high consumption for passive houses, but is still significantly lower than the average for Norway, which is 214 kWh/m² *yr (Energy consumption 2012).*

Characteristics of the household, such as the number of occupants and installed appliances affects for how much electricity each household uses.
Also position of the house is important factor on energy use. House in the middle will need less energy than those on the edge.
If we had information about number of occupants, their age and behavior it would be easy to explain these results.
It is clear that homes with small children and teenagers use more energy than households with adults.

Heating energy use can be reduced by setting radiator on lower temperature, and turning of when house is not occupied.
We have information that some households use heating in the bathroom even in the summer, what is explanation for high electricity use in the summer season.

In the analysis of energy use by end-users is assumed that largest energy use is for lighting, which should not be true, but in the most of the cases it is.

From simulation with radiator it can be concluded that appropriate heating can not be achieved with only one radiator on the floor, and that is why some households have installed additional heating cables.

Energy efficiency is a continuous process and does not end with the construction of an efficient object, but continues with energy use monitoring, identifying new saving potentials and implementation of new measures to improve energy efficiency.
For good energy planning is important to know how much energy was used in last years.
Considering the growth of living standard, it is expected that more energy will be used in the future in order to make indoor thermal environment more comfortable.

We can conclude that users did not buy their passive houses because they were energy efficient, but because of their location and view.
The findings of this study shows that the most important characteristics of what determines which house to buy is its location, type of house including size, price and number of rooms, as well as closeness to nature. Characteristics such as garden size, view and control over the floor plan were initially desired but were disregarded while compromising to find an available house. The financial benefit of the low energy consumption, as well as the reduced environmental impact was a positive addition to the house choice, but was not influencing the house choice (*Does Sustainable Building Technology Matter to Home Buyers*).

All this result shows that there is potential for energy savings.

Simple steps to increase energy efficiency without additional cost are:

- Adjust heating at night and when no one is in the house,
- In the night turn down the blinds and draw the curtains to avoid losses
- In the heating season reduce the room temperature by 1 ° C
- Using natural lighting as much as possible and turn off lights in a room when not needed
- Turn off computers, TVs and other appliances when not in use to avoid losses on so-called. stand-by mode

There is information from one user which can be good description for situation in this area: „This gives exactly the same annual consumption that we had at our old house from 1966 that was 70 m² bigger… We had expected considerably less electricity / district heating consumption. "

12. Future work

Used simulation techniques can hardly produce real house energy use data.

In the continuation of the work it should be done further studies about:

- The occupant behavior on heating use
- The occupant activities on turn on/off lightings
- The occupant activities on turn on/off appliances
- The energy use with different operation manner

For the future work it would be good to investigate change in user's behavior, whether living in a passive house would change their consciousness and their attitude to the environment.
In a Norwegian study on low-energy houses it was found that 12% of the participants reported a high degree of increased pro-environmental behavior, and 77% report some increase after moving into the low-energy houses *(Kleiven, 2007).*
This research field should be investigated more precisely.

13. Acknowledgement

I really value this opportunity to work on my master thesis at NTNU in Trondheim. I have met a lot of interesting people there. I wish to thank my supervisor Professor Natasa Nord, for giving me guidance and for helping me to create this thesis.
I would also like to thank people from Heimdal Development Company, they were very helpful to provide me relevant data.

I would like to thank everyone who helped in this project. Special gratitude goes to professor Vojislav Novakovic who made possible my stay at NTNU.

Now, this thesis is finished. My stay on NTNU is also finished.
For this months spent in Norway, I have fall in love with this amazing country. And I really appreciate for all the people I have met and all the fantastic things that happened in my life. Those are precious memories forever.

14. Reference

Abel, E. & Elmroth, A., (2007). The energy balance in residential buildings. ISBN:978-91-540-5997-3, *Buildings and Energy-a systematic approach.* Printing and repro: Alfaprint, pp.123.

Anna Karina Carlsson, (2011). *Does Sustainable Building Technology Matter to Home Buyers*

Bøeng, A. C., & Larsen, B. M. (2008). *Husholdningenes energiforbruk: Vi bruker mindre energi i hjemmet enn før*. Retreived from Statistisk Sentralbyrå website: http://www.ssb.no/ssp/utg/200804/10/.

Dr. Wolfgang Feist, (2007). *PASSIVE HOUSE INSTITUTE,* website: http://www.passivehouse.com/.

Dr. Charles Xie, (2010). Softwer Energy2D

Kleiven, T. (2007). *Brukerundersøkelse i Husby Amfi*. (Rapport SBF BY A07022) Trondheim: SINTEF Byggforsk.

Lovdata, Editor. (2010). Norsk Lovtidend. TEK10, *Byggteknisk forskrift.*

Lovdata, Editor. (2010). Norsk Lovtidend. TEK07, *Byggteknisk forskrift.*

Norwegian Water Resources and Energy Directorate (2012). *Energy consumption 2012, Household energy consumption.*

NS3700, *Kriterier for passivhus og lavenergihus. Boligbygninger.* 2010, Standard Norge.

NS3031, *Beregning av bygningers energiytelse. Metode og data.* 2007, Standard Norge.

Richard Seifert, (2011). *Appliance Energy Use and Costs in Alaska*

Sara Ghaemi, Guenther Brauner, (2009) *User behavior and patterns of electricity use for energy saving.*

Sartori, Wachenfeldt, & Hestnes (2009). *Energy demand in the Norwegian building stock: Scenarios on potential reduction*

SINTEF Byggfors Bygninger (2010) *Miljøbyen Granås Energikonsept.Rekkehus.*

SINTEF Byggfors Bygninger (2010) *Miljøbyen Granås Energikonsept* Enebolig

Xrgia. (2011). *Energibruk i lavenergi- og passivbygg. Oslo: Energi Norge.*

Standards Norway. (11.04.11]; Available from: *http://www.standard.no/en/.*

Trondheim Kommune – Miljøenheten, (2010) ECO-City Trondheim

Ulla Janson (2008). Passive houses in Sweden, Experiences from design and construction phase)

Purmo technical brochure. available from *http://www.purmo.com/fi*

http://arkitektur.no/miljobyen-granasen-eneboliger

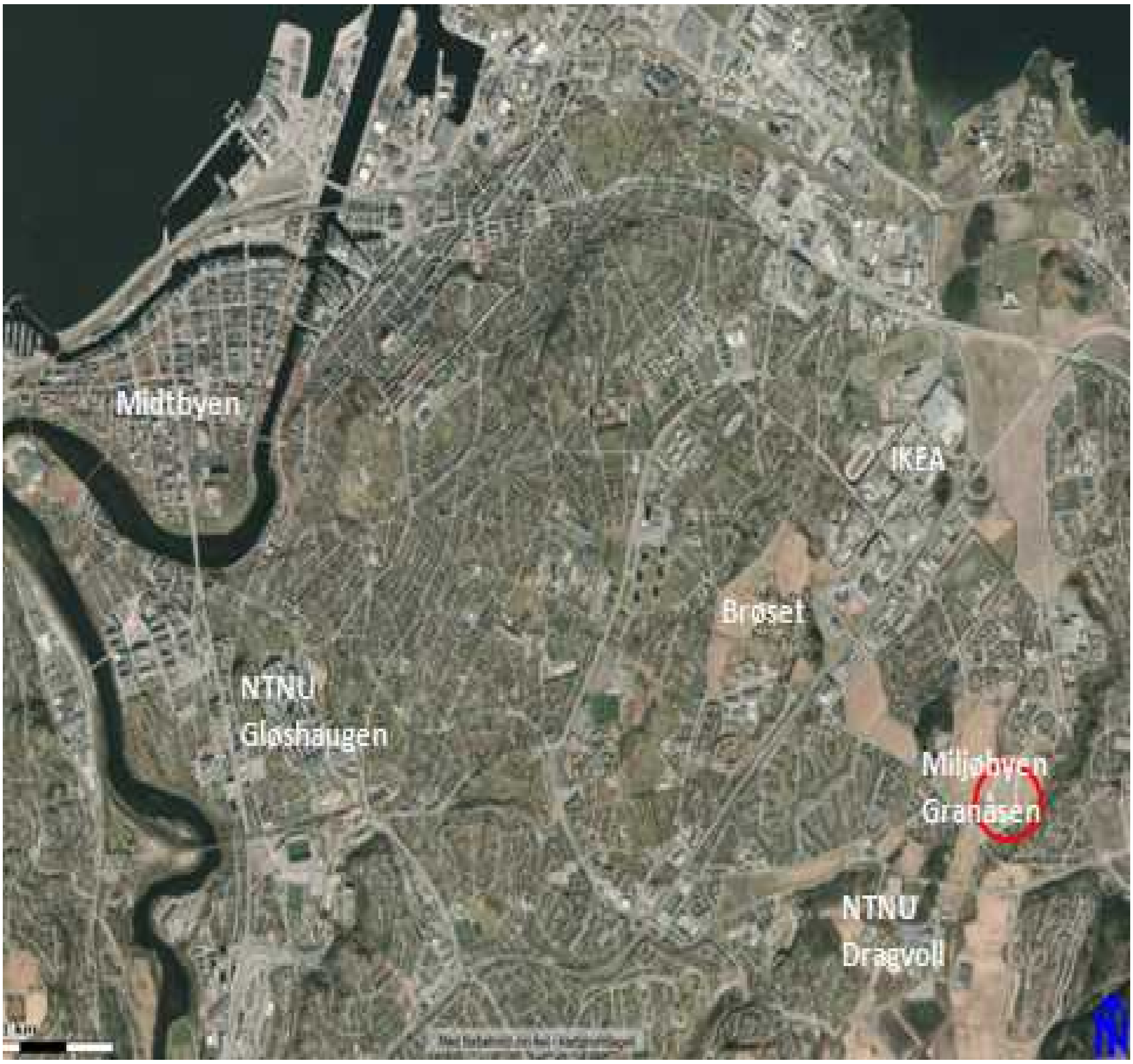
http://maps.google.no/

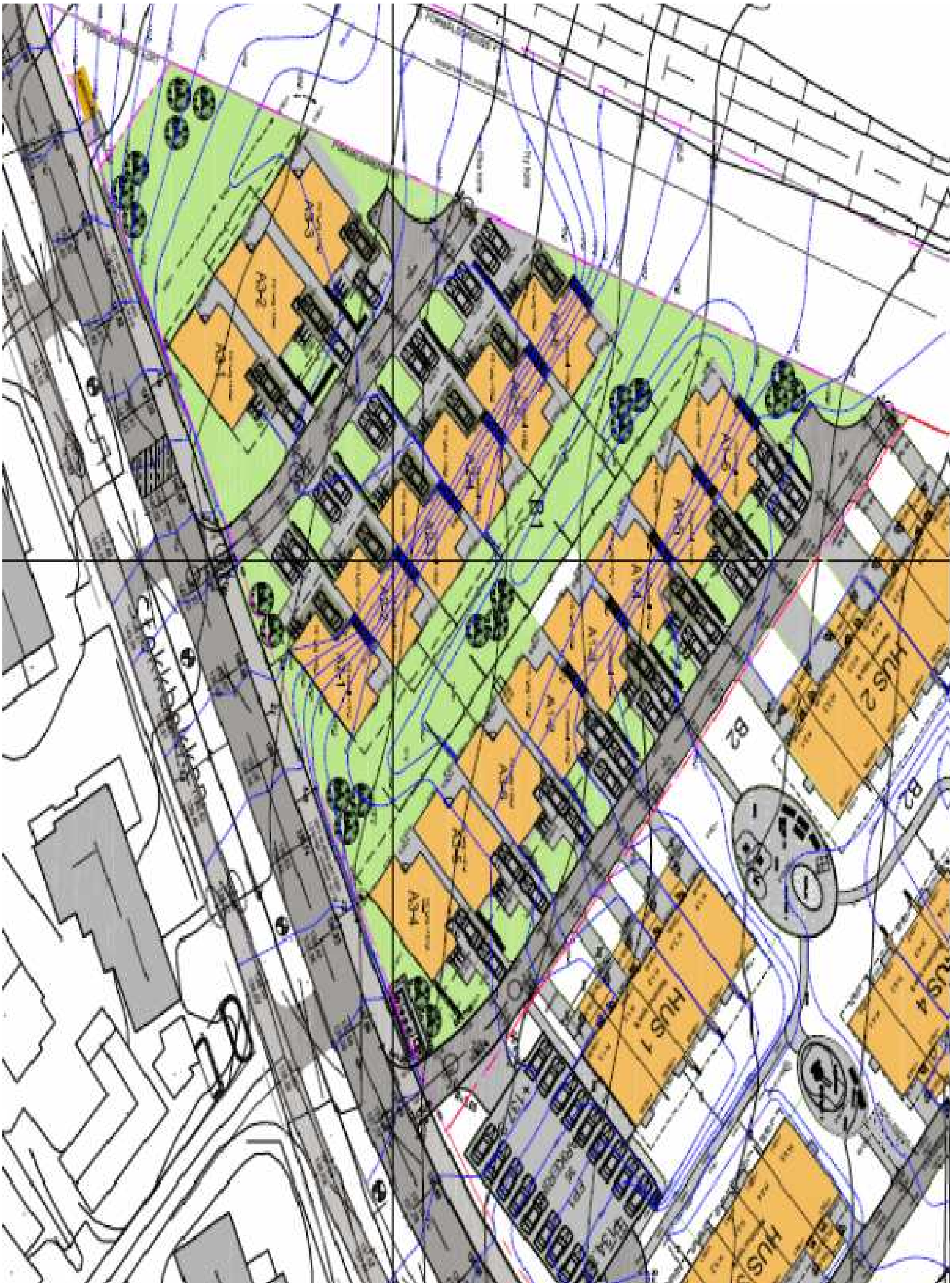
http://weatherspark.com/history/28896/2012/Stj-rdal-Nord-Trondelag-Norway

http://arkitektur.no/miljobyen-granasen-eneboliger

Appendix

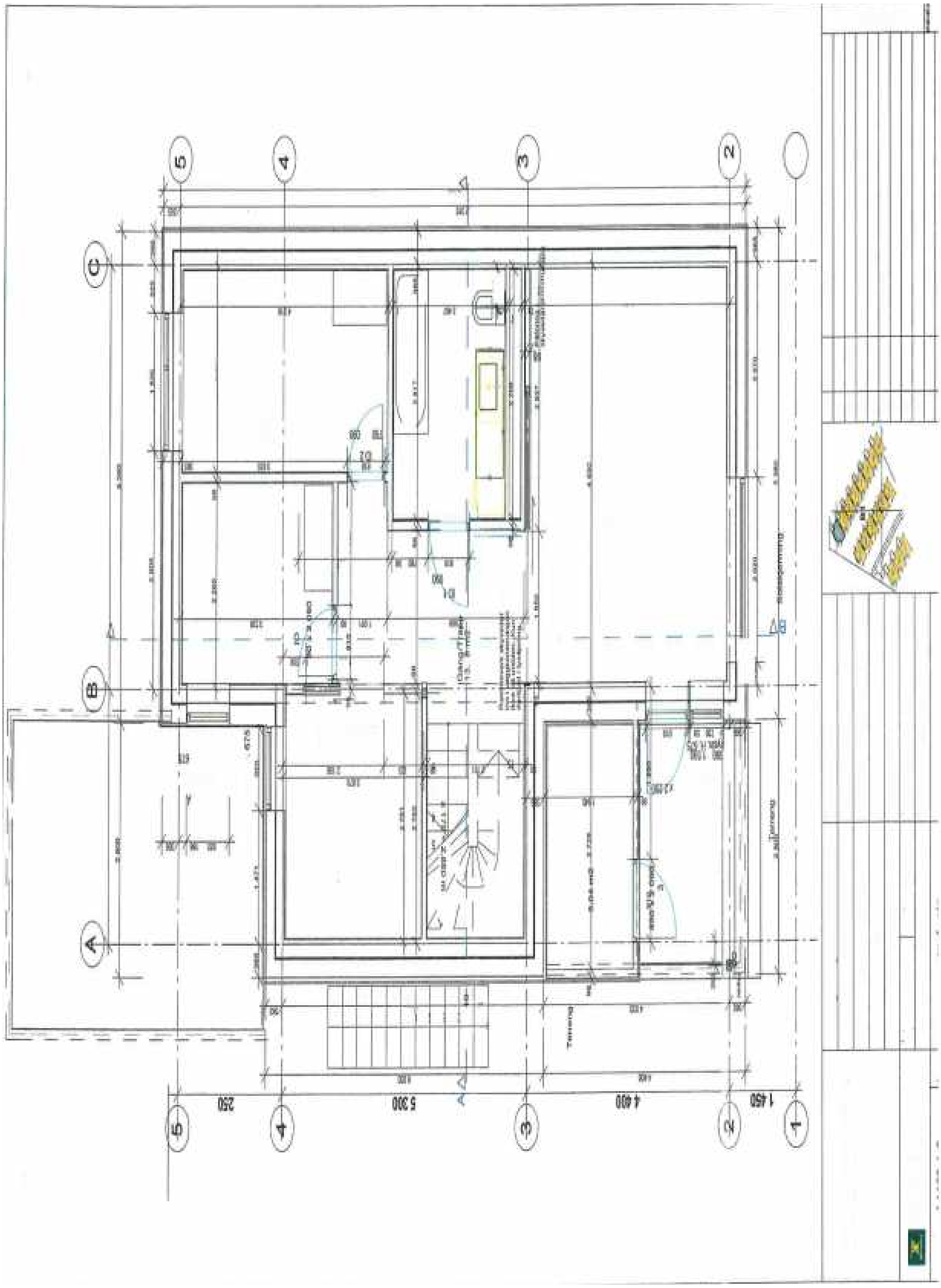
Appendix 1: Sketches of area

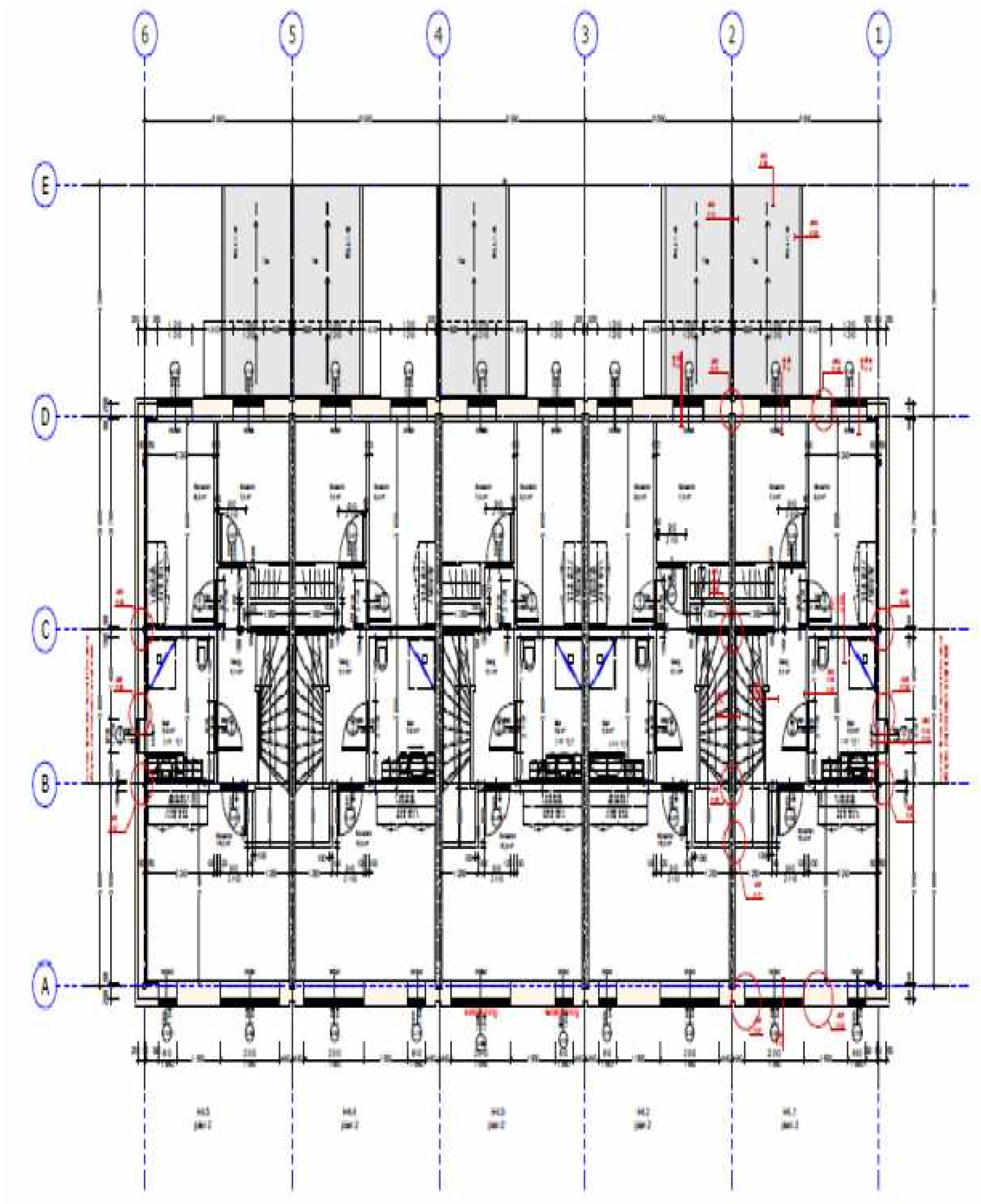



HUS 1
HUS 2
HUS 3
B1
B2


HUS 8
HUS 7
HUS 6
FP2
PARKERING
B18
B2
HUS 5
HUS 4
HUS 3
B2
HUS 2
HUS 1
FP1
PARKERING
B2
B1
A1-6
A1-5
A1-4
A1-3
A1-2
A3-6
A3-5
A3-4
FGA1
OFFENTLIG FRIOMRÅDE
GRUSDEKKE
BREDDE 2,0 M INKL LIST
STORGATESTEIN
TRAFO FOR
TEV

Original sketches from the architect




6
5
4
3
2
1
E
D
C
B
A

Appendix 2: Tables used in calculations- energy use in some houses

D1

Dato	Electricity	Consumption	District Heating	Consumption	Date of reading
1.3.2012	2355	2355	1329	1329	5.3.2012
1.4.2012	3235	880	2057	728	1.4.2012
1.5.2012	4434	1199	2456	399	1.5.2012
1.6.2012	5435	1001	2800	344	1.6.2012
1.7.2012	5944	509	3179	379	29.6.2012
1.8.2012	6106	162	3318	139	1.8.2012
1.9.2012	6695	589	3777	459	1.9.2012
1.10.2012	7448	753	4231	454	1.10.2012
1.11.2012	8306	858	4924	693	1.11.2012
1.12.2012	9255	949	5902	978	1.12.2012
1.1.2013	10244	989	7055	1153	1.1.2013
1.2.2013	11497	1253	8204	1149	1.2.2013

D2

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.3.2012	2421	2421	1581	1581	5.3.2012
1.4.2012	3069	648	3074	1493	18.4.2012
1.5.2012	3512	443	3782	708	15.5.2012
1.6.2012	3805	293	4317	535	6.6.2012
1.7.2012		337		537	
1.8.2012	4479	337	5390	537	12.8.2012
1.9.2012	4841	362	6095	705	13.9.2012
1.10.2012	5212	371	6890	795	15.10.2012
1.11.2012	5625	413	7759	869	11.11.2012
1.12.2012	6255	630	9122	1363	13.12.2012
1.1.2013	6990	735	10593	1471	14.1.2013
1.2.2013	7446		12195		

D3

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.3.2012	3256	3256	648	648	9.3.2012
1.4.2012	3989	733	954	306	10.4.2012
1.5.2012	4379	390	1560	606	1.5.2012
1.6.2012	4866	487	1949	389	4.6.2012
1.7.2012	5169	303	2185	236	1.7.2012
1.8.2012	5379	210	2336	151	1.8.2012
1.9.2012	5774	395	2546	210	5.9.2012
1.10.2012	6353	579	2913	367	1.10.2012
1.11.2012	7115	762	3461	548	31.10.2012
1.12.2012	7825	710	4220	759	1.12.2012

1.1.2013	8777	952	5267	1047	2.1.2013
1.2.2013	9742	965	6274	1007	1.2.2013

D4

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.3.2012	1760	1760	1893	1893	19.3.2012
1.4.2012	2045	285	2303	410	1.4.2012
1.5.2012	3107	1062	3358	1055	1.5.2012
1.6.2012	4389	1282	4024	666	1.6.2012
1.7.2012		923		374	
1.8.2012	6235	923	4771	374	10.8.2012
1.9.2012	6979	744	5432	661	1.9.2012
1.10.2012	8015	1036	6174	742	8.10.2012
1.11.2012	9182	1167	7027	853	1.11.2012
1.12.2012	10368	1186	8028	1001	1.12.2012
1.1.2013	11757	1389	9174	1146	1.1.2013
1.2.2013	13060	1303	10292	1118	1.2.2013

D5

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.3.2012	2399	2399	267	267	16.3.2012
1.4.2012	3482	1083	114	-153	12.4.2012
1.5.2012	4174	692	1741	1627	2.5.2012
1.6.2012	5611	1437	2867	1126	21.6.2012
1.7.2012		1204		766	
1.8.2012	6257	646	3633	1245	10.8.2012
1.9.2012	7146	889	4403	770	13.9.2012
1.10.2012		1486		1123	
1.11.2012		1486		1123	
1.12.2012	10214	1562	6649	2612	2.12.2012
1.1.2013		1562		1245	
1.2.2013	13338	1204	9261	2211	1.2.2013

D6

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.3.2012	2500	2500	915	915	16.3.2012
1.4.2012	3539	1039	1660	745	9.4.2012
1.5.2012	4572	1033	2324	664	1.5.2012
1.6.2012	5668	1096	2937	613	1.6.2012
1.7.2012	6747	1079	3491	554	2.7.2012
1.8.2012	7216	469	3879	388	31.7.2012
1.9.2012	8269	1053	4627	748	3.9.2012
1.10.2012	9299	1030	5380	753	1.10.2012
1.11.2012	10503	1204	6235	855	31.10.2012

1.12.2012	12053	1550	7400	1165	2.12.2012
1.1.2013	14077	2024	9185	1785	12.1.2013
1.2.2013	15167	1090	10465	1280	5.2.2013

T1

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	516	516	696	696	27.6.2012
1.8.2012				680	
1.9.2012	1531	1015	1376	447	9.9.2012
1.10.2012	2128	597	1823	652	3.10.2012
1.11.2012		1573		652	
1.12.2012	3701	1202	3127	1024	1.12.2012
1.1.2013	4903	1018	4151	859	2.1.2013
1.2.2013	5921	910	5010	830	17.2.2013
1.3.2013	6831	1148	5840	969	2.3.2013
1.4.2013	7979	834	6809	535	5.4.2013
1.5.2013	8813	1408	7344	1016	5.5.2013
1.6.2013					

T2

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	817	817	599	599	27.6.2012
1.8.2012	1511	694	1059	1000	1.8.2012
1.9.2012	1764	253	1243	184	1.9.2012
1.10.2012	2320	556	1560	307	1.10.2012
1.11.2012	3054	734	1867	336	30.10.2012
1.12.2012	4050	994	2203	356	1.12.2012
1.1.2013	5235	1185	2559	434	31.12.2012
1.2.2013	6286	1051	2993	320	1.2.2013
1.3.2013	7013	704	3313	509	1.3.2013
1.4.2013	7717	655	3821	651	2.4.2013
1.5.2013					
1.6.2013	8924	495	4472	222	2.6.2013

T3

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	536	536	603	603	27.6.2012
1.8.2012	1325	789	970	367	1.8.2012
1.9.2012	1932	607	1587	617	1.9.2012
1.10.2012	2571	639	2187	600	30.9.2012
1.11.2012	3485	914	2930	743	1.11.2012
1.12.2012	4478	985	3451	521	1.12.2012
1.1.2013	5744	1266	4267	816	29.12.2012
1.2.2013	6918	1174	5151	719	2.1.2013
1.3.2013	7856	938	5870	715	1.3.2013
1.4.2013	8919	1063	6585	633	2.4.2013

1.5.2013	9700	781	7218	486	8.5.2013
1.6.2013	10384	684	7704	496	3.6.2013

T4

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	1140	1104	586	586	28.6.2012
1.8.2012		1420		837	
1.9.2012	2560	746	1423	472	1.9.2012
1.10.2012	3306	879	1895	481	1.10.2012
1.11.2012	4185	874	2376	503	1.11.2012
1.12.2012	5059	883	2879	579	1.12.2012
1.1.2013	5942	914	3458	692	2.1.2013
1.2.2013	6856	856	4150	479	1.2.2013
1.3.2013	7712	888	4629	443	3.3.2013
1.4.2013	8600	694	5072	354	11.4.2013
1.5.2013	9294	1046	5426	756	7.5.2013
1.6.2013		610		418	

T5

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	136	136	343	343	3.7.2012
1.8.2012		725		575	
1.9.2012	861	596	918	454	9.9.2012
1.10.2012	1457	711	1372	479	2.10.2012
1.11.2012	2168	941	1851	519	4.11.2012
1.12.2012	3109	879	2370	480	7.12.2012
1.1.2013	3988	1086	2850	594	2.1.2013
1.2.2013	5073	751	3444	532	4.2.2013
1.3.2013	5824	804	3976	675	4.3.2013
1.4.2013	6628	815	4651	623	3.4.2013
1.5.2013		815		623	
1.6.2013					

T6

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	209	209	198	198	3.7.2012
1.8.2012		681		748	
1.9.2012	890	462	950	496	3.9.2012
1.10.2012	1352	548	1446	394	1.10.2012
1.11.2012	1900	580	2165	719	31.10.2012
1.12.2012	2480	549	2994	1106	1.12.2012
1.1.2013	3029	700	4100	924	1.1.2013
1.2.2013	3729	700	5024	999	1.2.2013
1.3.2013	4340	560	6025	945	2.3.2013
1.4.2013	4900	472	6970	655	3.4.2013

1.5.2013	5372	408	7625	471	1.5.2013
1.6.2013	5780		8096		3.6.2013

T8

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	74	74	143	143	6.7.2012
1.8.2012		810		840	
1.9.2012	884	509	983	698	7.9.2012
1.10.2012	1393	643	1681	1049	1.10.2012
1.11.2012	2036	1987	2730	2050	1.11.2012
1.12.2012		1320		1382	
1.1.2013	4023	865	4780	1016	28.12.2012
1.2.2013	5343	1010	6162	1157	1.2.2013
1.3.2013	6208	557	7178	664	1.3.2013
1.4.2013	7218	1645	8335	330	8.4.2013
1.5.2013	7775		8999		1.5.2013
1.6.2013					

T9

Dato	Elektrisitet	Forbruk	Fjernvarme	Forbruk	Avlest dato
1.7.2012	169	169	46	46	10.7.2012
1.8.2012		675		531	
1.9.2012	844	502	577	434	31.8.2012
1.10.2012	1346	674	1011	491	5.10.2012
1.11.2012	2020	574	1502	612	31.10.2012
1.12.2012	2594	851	2114	1059	1.12.2012
1.1.2013	3445	721	3173	932	2.1.2013
1.2.2013	4166	699	4105	1006	31.1.2013
1.3.2013	4865	550	5111	727	6.3.2013
1.4.2013	5415	583	5838	474	3.4.2013
1.5.2013	5998	612	6312	475	1.5.2013
1.6.2013	6610	1019	6787	768	5.6.2013

Appendix 3: Electricity use by end-users for rest of the houses:

D1

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
plasma television	300	3	180	540	55,6
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		6		3,6
Tumble drier	1200		10		12
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		200		244
Lighting	2000		223,5		447
					1253,20645

D3

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	200	33
DVD player	40	3	180	100	10,2
Laptop	50	10	190	200	11,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		200		10
Dishwasher	1200		15		18
Hair Dryer	750		12		9
Toaster & broiler/oven	600		6		3,6
Tumble drier	1200		10		12
Clothes washer	512		7		3,584
iron	1100		4		4,4
Electric Oven	90		15		1,35
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1060		200		212
Lighting	2000		200		400
					965,90645

D4

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
plasma television	300	3	180	540	55,6
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		6		3,6
Tumble drier	1200		10		12
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		400		488
Lighting	2000		355		710
					1760,20645

D5

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television			180	3	220
plasma television			300	3	180
DVD player			40	3	180
PC			200	10	220
Laptop			50	10	190
Coffee Maker			600		9
Microwave			600	2	20
Fridge			300		720
Electronic Cleaner			50		400
Dishwasher			1200		30
Hair Dryer			750		12
Toaster & broiler/oven			600		10
Tumble drier			1200		15
Affiliation Quooker			120		15
Clothes washer			510		8
Iron			1100		5
Electric Oven			1100		20
Toothbrush			1,1		4,5
Waffle Iron			1200		2
Juicer			90		3
Mixer			80		3
Shaver			15		2,5
Underfloorheating wc and bathroom			1220		500
Lighting			2000		500
heating cable in hall			500		360

D6

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
plasma television	300	3	180	540	55,6
DVD player	40	3	180	540	88,2
PC	200	10	220	500	49
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		400		20
Dishwasher	1200		30		36
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5		5,5
Electric Oven	1100		20		22
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		2,5		3
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		500		610
Underfloorheating laundry	1071		20		21,42
Lighting	2000		500		1000
heating cable in hall	663		390		258,57
					2500,11245

D7

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
plasma television	300	3	180	540	55,6
DVD player	40	3	180	540	88,2
PC	200	10	220	500	49
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		400		20
Dishwasher	1200		30		36
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		10		5,1
Iron	1100		6		6,6
Electric Oven	1100		20		22
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		2		2,4
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		480		585,6
Lighting	2000		500		1000
					2197,15245

D9

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
DVD player	40	3	180	540	88,2
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		6		3,6
Tumble drier	1200		10		12
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		2		2,4
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		400		488
Lighting	2000		266		532
					1492,08645

D10

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
plasma television	300	3	180	540	55,6
DVD player	40	3	180	540	88,2
PC	200	10	220	500	49
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		400		20
Dishwasher	1200		30		36
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		6		6,6
Electric Oven	1100		20		22
Toothbrush	1,1		5		0,0055
Waffle Iron	1200		2,5		3
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		520		634,4
Lighting	2000		518		1036
heating cable in hall	663		520		344,76
					2626,383

D11

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	180	540	88,2
PC	200	10	220	500	49
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		400		20
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		6		6,6
Electric Oven	1100		15		16,5
Toothbrush	1,1		5		0,0055
Waffle Iron	1200		2,5		3
Juicer	90		3		0,27
Mixer	80		2		0,16
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		400		488
Lighting	2000		387		774
heating cable in hall	663		400		265,2
					2071,153

D12

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		25		30
Hair Dryer	750		11		8,25
Toaster & broiler/oven	600		7		4,2
Tumble drier	1200		10		12
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		2,5		0,2
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		325		396,5
Lighting	2000		200		400
heating cable in hall	663		325		215,475
					1518,39145

D13

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		26		31,2
Hair Dryer	750		11		8,25
Toaster & broiler/oven	600		7		4,2
Tumble drier	1200		12		14,4
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		2,5		0,2
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		350		427
Lighting	2000		200		400
heating cable in hall	663		350		232,05
					1569,06645

D14

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		250		305
Underfloorheating laundry	500		250		125
Lighting	2000		270		540
heating cable in hall	663		250		165,75
					1541,22245

T1

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	1100		16,5		18,15
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		300		366
Lighting	2000		400		800
					1573,12245

T2

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		20		24
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	1100		16,5		18,15
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		233		284,26
Lighting	2000		250		500
					1185,38245

T4

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		20		24
Hair Dryer	750		12		9
Toaster & broiler/oven	600		12		7,2
Tumble drier	1200		16		19,2
Affiliation Quooker	120		17		2,04
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	1100		16,5		18,15
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		315		384,3
Lighting	2000		315		630
					1418,06245

T5

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		20		24
Hair Dryer	750		12		9
Toaster & broiler/oven	600		12		7,2
Tumble drier	1200		16		19,2
Affiliation Quooker	120		17		2,04
Clothes washer	510		12		6,12
Iron	1100		5,5		6,05
Electric Oven	1100		16,5		18,15
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		230		280,6
Lighting	2000		200		400
					1086,40245

T6

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
plasma television	180	3	80	400	15,6
DVD player	40	3	120	540	6,6
Laptop	50	10	192	200	11,6
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Dishwasher	1050		15		15,75
Hair Dryer	750		5		3,75
Toaster & broiler/oven	600		4		2,4
Tumble drier	1800		8		14,4
Clothes washer	300		10		3
Electric Oven	1100		8		8,8
Juicer	90		1		0,09
Mixer	80		1		0,08
Shaver	15		3		0,045
Underfloorheating wc and bathroom	500		250		125
Lighting	600		250		150
					586,515

T7

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
plasma television	300	3	180	540	55,6
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		360		18
Dishwasher	1200		25		30
Hair Dryer	750		10		7,5
Toaster & broiler/oven	600		5		3
Tumble drier	1200		10		12
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		2		2,4
Juicer	90		3		0,27
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		440		536,8
Lighting	2000		445		890
					1987,38645

T8

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		200		10
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1000		15		15
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	900		11,5		10,35
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1000		180		180
Underfloorheating laundry	500		200		100
Lighting	1000		180		180
					851,32245

T9

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	150	3	220		33
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		200		10
Dishwasher	1200		17		20,4
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1000		12		12
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	900		11,5		10,35
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		2,5		3
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1000		150		150
Underfloorheating laundry	500		160		80
Lighting	1000		150		150
					749,12245

T10

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		25		30
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1200		15		18
Affiliation Quooker	120		15		1,8
Clothes washer	510		9		4,59
Iron	1100		5,5		6,05
Electric Oven	1100		16,5		18,15
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		380		463,6
Lighting	2000		382		764
					1635,23245

T11

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	220	500	42
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		300		15
Dishwasher	1200		20		24
Hair Dryer	750		12		9
Toaster & broiler/oven	600		12		7,2
Tumble drier	1200		16		19,2
Affiliation Quooker	120		17		2,04
Clothes washer	510		12		6,12
Iron	1100		5,5		6,05
Electric Oven	1100		11		12,1
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		3		3,6
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		200		244
Lighting	2000		180		360
					1003,75245

T12

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	150	3	220		33
DVD player	40	3	100	540	5,5
Laptop	50	10	190	500	12,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		200		10
Dishwasher	1200		17		20,4
Hair Dryer	750		12		9
Toaster & broiler/oven	600		10		6
Tumble drier	1000		12		12
Affiliation Quooker	120		15		1,8
Clothes washer	510		8		4,08
Iron	1100		5,5		6,05
Electric Oven	900		11		9,9
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		2,5		3
Juicer	90		4		0,36
Mixer	80		3		0,24
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1000		150		150
Underfloorheating laundry	500		300		150
Lighting	1000		295		295
					963,67245

T13

household apliances	maximum power (W)	standby power (W)	average use per month (h)	time in standbye	Monthly Avg kWh Use
LCD television	180	3	180	540	34
DVD player	40	3	180	540	88,2
PC	200	10	150	500	35
Laptop	50	10	190	500	14,5
Coffee Maker	600		9		5,4
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Electronic Cleaner	50		250		12,5
Dishwasher	1200		26		31,2
Hair Dryer	750		11		8,25
Toaster & broiler/oven	600		7		4,2
Tumble drier	1200		12		14,4
Clothes washer	512		7		3,584
iron	1100		4,5		4,95
Electric Oven	1100		15		16,5
Toothbrush	1,1		4,5		0,00495
Waffle Iron	1200		1,6		1,92
Juicer	90		3		0,27
Mixer	80		2,5		0,2
Shaver	15		2,5		0,0375
Underfloorheating wc and bathroom	1220		300		366
Lighting	2000		200		400
heating cable in hall	663		250		165,75
					1436,26645

T14

plasma television	180	3	80	400	15,6
DVD player	40	3	120	540	6,6
Laptop	50	10	192	200	11,6
Microwave	600	2	20	700	13,4
Fridge	300		720		216
Dishwasher	1050		15		15,75
Hair Dryer	750		5		3,75
Toaster & broiler/oven	600		4		2,4
Tumble drier	1800		8		14,4
Clothes washer	300		10		3
Electric Oven	1100		8		8,8
Juicer	90		1		0,09
Mixer	80		1		0,08
Shaver	15		3		0,045
Underfloorheating wc and bathroom	500		320		160
Lighting	600		308		184,8
					656,315