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Taking care of People and Planet

ASSESSING THE SUSTAINABILITY OF A SOCIAL CARE FARM

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PREFACE

This report is the result of my research for the Bachelor Degree in Civil Engineering at the University of Twente. This study is about improving the sustainability of social care farms. At Alldrik in Markelo, I found a place to do my research in a professional social care farm. I felt very welcome and enjoyed my stay. Besides performing the research there, I found it very interesting to hear and see the daily processes in a social care farm.

During this research I had a lot of help, for which I would like to thank several people. First, I want to thank Bram Entrop for supervising my Bachelor thesis. He helped me with critical comments and insightful advices throughout my graduation project. Not to forget Henk van der Giesen for his ideas and philosophy. Our discussions kept me going and I am very thankful for that. Also, I am Tineke van de Giesen and the care group very grateful for the huge amount of coffee and pleasant stories during the breaks.

Finally, I would like to thank my family for the endless trust and support.

Anders Sewalt

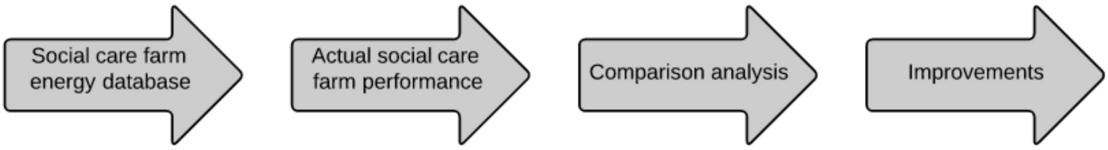
ABSTRACT

This research tests the possibility to develop a new energy performance label for social care farms. The Dutch Government is stimulating the application of energy efficiency measures to reduce the energy demand in the built environment, which is responsible for about 20% of the total CO_2 emissions in the Netherlands. For new residential buildings, there already set policy targets for 2020 and a benchmark to compare different buildings is available. However, for non-residential buildings, like social care farms, there is still much information unknown about the energy performance. It is hard to assess this energy performance of social care farms due to a lack of data. Therefore, social care farms have little urge to improve their energy efficiency. The aim of this research is to provide insight into the sustainability of social care farms by introducing a benchmark for their energy performance. The following research question is formulated to achieve this goal:

How can the adoption of sustainable techniques and measures take place in social care farms?

To establish the adoption of sustainable techniques and measures in social care farms, a guideline should be developed. First, a new energy performance label for social care farms is created by means of a literature study. In a case study is tested how the information for a new benchmark can be collected and analyzed. The eventual energy breakdown gives the first insights in possible energy efficiency measure to improve the sustainability of the social care farm in the case study.

As a result, a guideline is made for all the social care farms in the Netherlands. This guideline consists of four stages, see the figure of the process below. First, a database should be developed with the energy performance information of a significant number of social care farms. Second, the energy performance indicator will show the actual energy efficiency of a particular social care farm. Subsequently, a comparison analysis between different social care farms could be done by means of the energy performance indicator and the energy breakdown. Finally, the comparison analysis between the social care farms will provide insights into the most profitable improvements to become more sustainable with respect to energy efficiency.



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1 INTRODUCTION

The term 'sustainable building' often goes round in civil engineering, a field in which social, economic and environmental aspects play an increasingly important role. In this research, I will outline the elements concerning sustainable building by social care farms. This research is based on a case study of social care farm Alldrik from Markelo. First of all, the background of the research will be sketched. Subsequently, there will be focused on the research setup. This will eventually result in the problem definition and research questions of the research. The chapter will be concluded with a reading guide.

1.1 BACKGROUND

The climate is changing due to the temperature rises on earth. This temperature increase is caused by greenhouse gasses, such as CO_2, into the air (milieu centraal, 2016). Worldwide, our energy usage is increasing significantly to maintain the human standards of living. The built environment is responsible for 30-40% of this global energy use (Royal Institute of Chartered Surveyors, 2005). Climate change such as global warming emphasizes the need to improve the energy efficiency of humans. The research that is performed by Stern (2008) showed that improving the energy efficiency of the built environment is the most cost-effective way to reduce CO_2 emissions.

Targets have been set in the European Union with respect to achieving a lower overall energy use in the built environment. These targets should result in a reduction of the dependency on fossil fuels. The buildings, being the primary agent, are crucial towards achieving the European Union target to reduce the greenhouse gas emission by 80-95% by 2015 compared to 1990 (European Commission, 2012). As a result, companies are searching for methods to reduce their CO_2 emissions (ASCE, 2016).

Sustainability is a recurring notion when it comes to reducing emissions. Frej (2005) tried to make a translation of sustainability into the built environment. He states:

''Sustainable building is designed in a way that it imposes a minimum seizure in which case it makes the most efficient use of scarce raw materials, water and energy throughout the life cycle''

In addition to this definition, the IVBN (2009) made a connection to the business world. It was believed that sustainable goes beyond efficiency. They state:

''Simultaneously sustainability is functioning optimally by a large user satisfaction, a good indoor climate and it fully meets the needs of the user''

Both definitions point out how wide the term 'sustainability' can be seen. In general, sustainability can be identified with three words (Cramer, 2003): people, planet, and profit. In Elkington's Cannibals with forks (1999) refers People, Planet, Profit - also known as the Triple Bottom Line or Triple P - to a situation where the company's performance in economic viability, environmental friendliness, and social responsibility agree with each other. It can be conceived as a kind of triangle where all three ends have to be in equilibrium with each other (Figure 1). Each dimension, the social dimension, the environmental dimension and the economic dimension only work when all three are fully integrated into the operations of the organization.

Figure 1: Triple Bottom Line (Elkington, 1999)

The 'Triple Bottom Line' model is the basis of the Corporate Social Responsibility (MVO, 2016) policy of the Dutch government and applies to many organizations as a tool for the implementation of sustainable development. This research adopted translation of the Triple Bottom Line due to the high degree of acceptance by the Dutch government.

This research is focusing on a particular target group: the social care farms. In the paper of Chen, Okudan and Riley (2010) is a study mentioned about the sustainable performance criteria in the construction industry. These criteria are based on the Triple Bottom Line and the requirements of different stakeholders. By means of gathering information of interest parties through a questionnaire, the criteria in Table 1 were made. The table is based on concrete buildings, but it can display important factors in the overall built environment.

Table 1: an abbreviated version of the sustainable performance criteria for construction method selection in concrete buildings (Chen, Okudan, & Riley, 2010)

	Environmental criteria
Focus of clients/engineers	P1: site disruption P2: recyclable/renewable contents P3: energy efficiency in building use (thermal mass) P4: reusable/recyclable elements P5: material usage P6: energy use in design and construction
Focus of contractors/precasters	P7: waste P8: pollution generation P9: water use

There are sustainability indicators needed to frame these criteria by subject. In the master thesis about sustainability indicators in the design process by Heeren (2012), the criteria are distributed over several indicators. The sustainability indicators that apply to the reduction of CO_2 in existing buildings are as follows:

- Energy use (natural gas and electricity usage)
- Water consumption
- Material usage

In this research, it is decided to examine one of these indicators for social care farms. This choice is necessary due to the time limits and quality assurance. The research is based on existing social care farms, so it is hard to prepossess the lifecycle of materials. The energy use has a significant impact on reducing CO_2 emissions, significantly more than the water consumption. Therefore, it was decided to only assess the energy usage of social care farms . In this research, the energy use is the sustainability indicator that will provide the information about the energy performance of social care farms.

Problem definition

There are numerous studies performed dedicated to sustainability. Sustainability is an increasingly important term in everyday life, making it a popular subject for research. By using the site 'ScienceDirect', a good indication can be given about studies that already have been performed. Searching for the keyword sustainable and sustainability together gives 429.695 hits. It is clear that to be innovative on this topic, a particular target group is needed. My research is about the energy use of social care farms. If this topic is linked to the sustainable terms it gives 11.818 search results, like the paper about attractive empowerment-oriented and strengths-based practices in the community (Hassink, Elings, Zweekhorst, & Smit, 2009) and the article about a safe community between lines or addiction and the wider society (Elings & Hassink, 2008), but none of the studies have a connection to sustainable building or energy use.

From the examination of the published reports can be concluded that the energy usage of care farms has not been mapped yet. There is a problem during the transition to sustainability in the social care farm sector which can be linked to the issue of social care farm Alldrik. Alldrik wants to be innovative in the field of sustainability, but the owners do not possess the right knowledge. They have contacted the Wetenschapwinkel UT and they have it deposited at the Platform for Research in Energy for a Sustainable Built environment (PRESBE) of the University of Twente. The issue consisted of the question of the possibilities of further sustainability of the social care farm.

Alldrik can be seen as the representative of all the social care farms/accommodations who want to become more sustainable, but have not enough understanding of the topic.

The identified issue of care farm Alldrik will lead to the framework of this research. It is necessary for these institutes to gain insight into the possibilities of being more sustainable. These insights have to ensure that the threshold for social care farms will decrease to implement sustainable improvements. A building energy performance assessment can provide credible information regarding how much energy is being consumed and how the performance is being appraised comparing with benchmarks. This should consequently be a motivation to improve the energy efficiency when the performance is deficient. Therefore, the following problem definition is given:

''There is currently limited insight by social care farms/accommodations into the possibilities of becoming more sustainable, but this knowledge is needed in order to reduce the CO_2 emissions''

Relevance

The challenge of Alldrik is consistent with the objectives of the municipality of Hof van Twente. The municipality of Hof van Twente wants to be an energy neutral municipality by 2035 (Hof van Twente, 2016). This goal can only be achieved as the church, entrepreneurs, residents, etc. are willing to work together. Energy conservation is an important tool, but also the production of energy from renewable energy sources (e.g. biomass, solar and the wind).

Furthermore, this research study is relevant to address the province of Overijssel. The province of Overijssel and her 25 municipalities, including Hof van Twente, have signed an agreement to ensure that by 2020 at least 45% of the owner-occupied dwellings have an energy label B or lower. In coming years, various activities will be developed in the community to achieve this together with the entrepreneurs and residents (Hof van Twente, 2016).

This research will help social care farms/accommodations to take steps in becoming sustainable so that the demand for energy will decrease. This decrease can contribute to the reduction of CO_2. This argument will make the research scientifically relevant, but that is not the only relevant aspect it approaches. The care sector aims to provide the best care for the least money. A waste of energy will cause that the costs will be retrieved by the clients. This is a social matter because with lower bills more people can profit from social care farms. Another socially relevant matter is the image of the social care farm. Becoming a sustainable social care farm can help to stand out of the abundance. This makes the social care farm unique and an example for others.

1.2 RESEARCH SETUP

Goal definition

The purpose of this research is lower the threshold for social care farms to become more sustainable. With the help of an assessment framework can the sustainability, in the field of energy performance, of a social care farm can be made transparent in comparison with other social care farms. This research aims at developing this assessment framework for social care farms. A guideline with practical methods and possibilities can assist in this. The case of care farm Alldrik let lend themselves perfectly to participate in the benchmarking process for social care farms. This research should eventually result as the basis of a well-fitted method to classify the energy performance of social care farms.

This provides the following objective:

''The aim of this research is to provide insight into possibilities to improve the sustainability of social care farms by introducing a benchmark for their energy performance''

Research questions

This section introduces the research questions. A description of the used method per sub-question is given. The main question in the research is:

''How can the adoption of sustainable techniques and measures take place in social care farms?''

The main question is directly related to the objective of this research. Three sub-questions are drafted in order to answer the main question:

1. **What method for expressing the energy performance of social care farms can be developed?**
    a. What are existing methods for assessment of building energy performance?
    b. Which energy performance indicators are relevant for comparing social care farms?
    c. How can the implementation of energy performance certificates in social care farms be established?

2. **How is the actual energy use of a social care farm characterized?**
    a. What are the known figures of the energy usage in the Netherlands?
    b. What is the annual theoretical energy use of a social care farm?
    c. What is the annual actual energy use of a social care farm?

3. **What measures can a social care farm take to become more sustainable?**
    a. What is the energy use breakdown in a social care farm?
    b. Which measures or techniques are available for improving the energy efficiency?
    c. What are the effects of these measures/techniques?

1.3 READING GUIDE

The structure of this report is as follows:

- Chapter two is an introduction to the existing energy assessment methods and lays the foundation of the paper. Furthermore, Chapter 2 introduces the development process in order to find a suitable energy performance benchmark for social care farms.
- Chapter three examines the characteristic energy usage of social care farms and is subdivided into three main parts. Part one looks at the theoretical annual energy usage of the case study, the seconds part examines the annual energy bills of the utility company and the last part are actual measurements on site.
- Chapter four contains the energy breakdown of the case study and the fitted energy efficiency measure in order to reduce the energy demand.
- Discussions and further uncertainties are addresses in Chapter five.
- Conclusions and recommendations are drawn in Chapter six.

2 THE ENERGY PERFORMANCE OF SOCIAL CARE FARMS

In this chapter, a theoretical framework will be formed to assess the energy performance of social care farms. Pérez-Lombard et al. (2009) state that the energy certification should not only show the energy performance but must also contain information that allows users to compare and assess similar buildings. An attempt to describe a method for expressing energy performance and certification of buildings is the new European standard EN 15217 (2007). This method tried to encompass all procedures for the determination of the energy performance of a building in comparison with similar buildings (Figure 2). This method will be used as the basis for the development of a new energy performance certificate for social care farms. First, the existing methods for buildings energy performance assessment will be described. Subsequently, a guideline for a new energy performance certificate for social care farms is made.

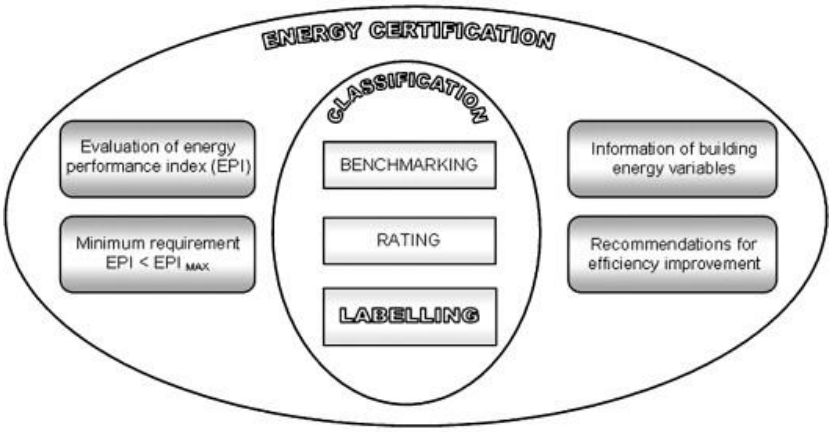

Figure 2: scope of the new European building energy certification method (EN 15217, 2007)

2.1 EXISTING METHODS FOR ASSESSMENT OF BUILDING ENERGY PERFORMANCE

In 2002, the European Union acknowledged the need for a new primary legislative instrument for improving the energy efficiency of the European building stock and introduced the Energy Performance Building Directive (EPBD) (2002/91/EC) and later the EPDB recast (2010/31/EU) (Dascalaki, Balaras, Gaglia, Droutsa, & Kantoyiannidis, 2012). The main objective of the EPBD is to promote the improvement of the energy performance of buildings within the European Union, including the local conditions and outdoor climate, as well as indoor climate requirements and cost-effectiveness (European Union, 2010). The EPBD requires the European Member States to set performance standards for buildings by applying energy performance certificates to buildings. This means that all the Member States should use a method with a common background to assess the energy performance of buildings (Andalore, Salomone, Loppolo, & Andalore, 2010). This common background is based on the general framework that is prescribed in the annex of the EPBD, as is shown in Table 3.

The methodology for calculating the energy performance of buildings should be in accordance with this general framework. The general framework states that the basis input data (the calculated or actual annual energy that is used in order to achieve a comfortable climate and to satisfy hot water needs) will lead to an energy performance indicator (EPI) and a numeric indicator of primary energy use in standardized usage situation. It also lists the aspects that should take into consideration in the calculation of the energy performance of a building.

In 2008, the Netherlands implemented the EPBD. As a result, the introduction of the Dutch measurement method, based on the 'Decree on Energy Performance of Building' (BEG) and the 'Regulation on Energy Performance of Buildings' (REG) (Filippidou, Nieboer, & Visscher, 2016). The energy performance of both new and existing buildings is expressed by the Energy Index (EI), a number which is ranging from ≤ 0.5 (extremely good performance) to ≥ 2.9 (extreme bad performance). The calculation methodology of the EI is described in NEN 7120 and in 82.3.-ISSO (ISSO, 2009). The EI is calculated as follows:

$$EI = \frac{Q_{total}}{C_1 \times A_{floor} + C_2 \times A_{loss} + C_3}$$

Where:

EI = Energy Index calculated to comply with the EPBD (-)
Q_{total} = annual energy demand (MJ)
A_{floor} = total ground surface (m^2)
A_{loss} = total thermal transmission surface (m^2)
C_1, C_2, C_3 = numerical correction factors 155 (MJ/m^2), 106 (MJ/m^2), 9560 (MJ)

The annual energy demand is the modeled characteristic primary use of a building in a standardized usage situation. It is possible that the total annual energy demand is a negative number if, for example, the energy generation of the photovoltaic systems is greater than the rest of the systems. In that case, the building will be called a net-zero energy building (nZEB), this will be further explained in Section 4.2. The breakdown of the total annual energy demand is as follows:

$$Q_{total} = Q_{space} + Q_{water} + Q_{aux} + Q_{light} - Q_{pv} - Q_{cog}$$

Where:

Q_{total} = total annual energy demand (MJ)
Q_{space} = annual energy demand for space heating (MJ)
Q_{water} = annual energy demand for heating domestic hot water (MJ)
Q_{aux} = annual additional energy (auxiliary electric energy) (MJ)
Q_{light} = annual energy demand for lighting of communal areas (MJ)
Q_{pv} = annual energy generation by photovoltaic systems (MJ)
Q_{cog} = annual energy generation by cogeneration (MJ)

Originally, the calculation of the EI is the basis of the Energy Label in the Netherlands. There was a correlation between the EI to the Energy Label and the mean actual primary energy usage based on a study performed on 200.000 dwellings in the Netherlands because there was no direct connection to the theoretical energy use (Majcen, Itard, & Visscher, 2013). Table 2 shows the correlation between the EI, label category and mean actual primary energy usage. The label category A++ represent the best energy performance and the G classification the worst.

Table 2: connection of Energy Index with Energy Label in the Dutch context (Majcen, Itard, & Visscher, 2013)

Energy Label	**Energy Index**	**Mean actual primary energy usage ($kWh/m^2/year$)**
A (A+, A++)	< 1,05	138,48
B	1,06 – 1,30	162,08
C	1,31 – 1,60	174,27
D	1,61 – 2,00	195,60
E	2,01 – 2,40	211,55
F	2,41 – 2,90	223,83
G	> 2,90	232,10

Table 3: common general framework for the calculation of energy performance of buildings (European Union, 2010)

1.	The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.
2.	The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for onsite production. The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC.
3.	The methodology shall be laid down taking into consideration at least the following aspects: 1. the following actual thermal characteristics of the building including its internal partitions: a. thermal capacity; b. insulation; c. passive heating; d. cooling elements; e. thermal bridges; 2. heating installation and hot water supply, including their insulation characteristics; 3. air-conditioning installations; 4. natural and mechanical ventilation which may include air-tightness; 5. built-in lighting installation (mainly in the non-residential sector); 6. the design, positioning, and orientation of the building, including outdoor climate; 7. passive solar systems and solar protection; 8. indoor climatic conditions, including the designed indoor climate; 9. internal loads.
4.	The positive influence of the following aspects shall, where relevant in the calculation, be taken into account: 1. local solar exposure conditions, active solar systems and other heating and electricity systems based on energy from renewable sources; 2. electricity produced by cogeneration; 3. district or block heating and cooling systems; 4. natural lighting,
5.	For the purpose of the calculation buildings should be adequately classified into the following categories: 1. single-family houses of different types; 2. apartment blocks; 3. offices; 4. educational buildings; 5. hospitals; 6. hotels and restaurants; 7. sports facilities; 8. wholesale and retail trade services buildings; 9. other types of energy-consuming buildings.

Since January 1st 2015, the EI calculation in the Netherlands changed and is based on a point system (ISSO, 2014). Up to July 2016, the EI and Energy Label are no longer directly linked to each other (RVO, 2016). They are two different methods that do look similar but are not identical. In the determination of the Energy Label, the comprehensive input of the EI calculation is translated to 10 parameters that will influence the label. There occurs a simplification in the translation to the Energy Label. Within the Energy Label is less nuance possible due to the 10 parameters, where the whole EI calculation has more than 150 parameters (RVO, 2016). An applicant requesting for the Energy Label should give the following 10 parameters as shown in Table 4:

Table 4: dwelling characteristics Energy Label (RVO, 2016)

1.	Year of construction	**2.**	Floor insulation
3.	Type of dwelling	**4.**	Type of heating system
5.	Type of glass	**6.**	Type of domestic hot water bathroom
7.	Facade insulation	**8.**	Type of ventilation system
9.	Roof insulation	**10.**	Solar panels and solar water heater

Energy Performance Coefficient

Dwellings built in 1998 or later have received a so-called energy performance coefficient (EPC). The EPC evaluates the energy efficiency of a dwelling/residential building or utility construction. This is based on building characteristics, facilities, and standard user behavior. The calculation of the EPC was submitted together with the application for the building permit. When the building permit is not older than 10 years, the EPC can be used instead of the Energy Label (BLG Wonen, 2016).

Since 1995, a system of energy performance standardization is in operation in the Netherlands (Gilijamse & Jablonska, 2002). In the Dutch Building Code compulsory is mentioned that the Energy Performance Coefficient (EPC) for new dwellings may not exceed a certain standard, the Energy Performance Norm (EPN). The EPC is a measure of the primary energy usage associated with space heating, ventilation, domestic hot water consumption and lighting, and includes auxiliary energy for pumps etc. The EPC is calculated for a standardized user behavior. The calculation formula is as follows: (van Cruchten, 1998):

$$EPC = \frac{Q_{total}}{C_1 \times A_{floor} + C_2 \times A_{loss}} \times \frac{1}{C_{EPC}}$$

Where:

EPC = Energy Performance Coefficient (-)
Q_{total} = annual energy demand (MJ) based on NEN 5128
A_{floor} = total floor surface (m^2)
A_{loss} = total thermal transmission surface (m^2)
C_1, C_2 = numerical correction factors (330 MJ/m^2, 65 MJ/m^2)
C_{EPC} = correction factor to fit past EPC results (-)

The total energy usage is corrected for the use surface and the surface of the building envelope. The purpose of this correction is that dwellings in which the same measures have been adopted also have the same EPC. Larger dwellings and dwellings with relatively large outer surface obtain thereby an extra 'energy budget'. The normalization is chosen such way that an EPC of 1,0 in an average dwelling corresponds to a usage of 1000 m^3 of natural gas per year (Gilijamse & Jablonska, 2002). The EPC applies only to new buildings; there are no applied obligations for the existing dwellings with respect to the energy performance.

By January 1st 2015, the EPC requirement on the energy performance of buildings is tightened and adjusted in the Building Act. The adjustment represents a tightening of the requirement up to 50% compared to 2007 (WE adviseurs & Arcadis, 2013). The new EPC requirement for dwellings and residential buildings is 0,4. The EPC for utility buildings depends on the functional use, see Table 5 below.

Table 5: the regulatory exposure EPC limit per functional use in 2007-2015 (WE adviseurs & Arcadis, 2013)

Limit value EPC Functional use	**2007**	**2013**	**2015**	**Δ2015 2007/2013**
Dwellings and residential buildings	0,8	0,6	0,4	-50%/-33%
Gathering function	2,2	2,0	1,1	-50%/-33%
Cell function	1,9	1,8	1,0	-47%/-44%
Healthcare function different than bed zone	1,5	1,0	0,8	-47%/-20%
Healthcare function with bed zone	3,6	2,6	1,8	-50%/-31%
Office function	1,5	1,1	0,8	-47%/-27%
Logies function in accommodation building	1,9	1,8	1,0	-47%/-44%
Educational function	1,4	1,3	0,7	-50%/-46%
Sport function	1,8	1,8	0,9	-50%/-50%
Store function	3,4	2,6	1,7	-50%/-35%

Energy performance of buildings

The determination method for creating an EPC calculation is by July 1st 2012, the Energy Performance of Buildings (EPG) (NEN 7120). This standard describes the method of the schematization of the building and calculating the energy use of building installations. In order to determine the transmission losses for heating and cooling the NEN 7120 refers to the NEN 1068: thermal insulation of buildings. The energy use of ventilation NEN 7120 refers to the NEN 8088-1: ventilation and air permeability of buildings.

The calculation of the EPC should be performed according to NEN 7120. There are various calculation programs available that can be used, according to this standard, for an EPC calculation. The official suppliers of EPG software are (RVO, 2016): Blink, DGMR, De twee Snoeken, Uniec and Vabi Elements.

The Dutch EPG is based on a quite detailed energy balance for the building in a typical metrological year and under standardized building use. As a result, the energy usage in terms of the quantities of final energy carriers entering the building in a typical year. The final annual energy use values are subsequently converted into equivalent primary energy use requirements through standard conversion factors. Finally, the EPC is obtained by normalizing the total primary energy requirement with the primary demand of a similar standardized building. Note that this is a theoretical calculation and that actual energy demand, as registered by energy meters, has no influence. The formula EPG uses the following formula to calculate the EPC:

$$EPC = \frac{E_{PTot}}{E_{P;adm;tot}} \; x \; EPC_{req} \; x \; \frac{1}{C_{EPC}}$$

With:

E_{Ptot} = annual characteristic energy use (MJ)

$E_{P;adm;tot}$ = annual admissible characteristic energy use (MJ)

EPC_{req} = new buildings requirement EPC (-)

C_{EPC} = correction factor to fit past EPC results (-)

2.2 ENERGY-EFFICIENCY INDICATORS

In Section 2.1, the term Energy Performance Indicators (EPIs) was mentioned. The EPC that is used for new buildings in the Netherlands is normalized with a similar standardized building. It is difficult to compare the energy uses of buildings if there is no standard or benchmark available. Measuring the total energy use per time period does not cover enough influence factors to make comparisons. The Energy Performance Indicators used in Europe are quite similar to the Energy Use Intensities (EUI) of the Americans (EIA, 1995), both are ratios of energy use input to energy service output. In America, the EUI is commonly expressed in the total annual energy use distributed over the footprint of the building (EIA, 1995). This unit can be translated to the ‘European’ MJ/m^2/year and is the basis for the new EPI for the social care farms in this research. However, Sharp (1996) states that such a simple normalized EPI is insufficient to make a credible energy-use performance rating. By taking other variables that affect the energy usage in consideration, a new benchmark should be made using a multivariate linear regression approach to correlate variables that representing important characteristics of social care farms with the EPI.

It is necessary to categorize all the important variables that can influence the energy usage before the benchmarking process can start. The benchmarking method should take several factors into account that can influence the energy performance of a social care farm. Chung (2011) describes four main categories that have the biggest effect on this performance:

1. Random factors such as unusual weather conditions
2. Physical characteristics like age, the number of floors, etc.
3. Incentives faced by building management or the owners
4. Differences in how building occupant utilize end-use devices

The annual actual energy use performance of the social care farms should be normalized in consideration of the factors mentioned above. In this section is explained why and which variables are taken into account in the benchmarking process for social care farms.

Energy services

The systems that are present in a building have an influence on the energy demand. In general, there are four different systems (Vabi Elements, 2014): space heating, domestic hot water, lighting, and ventilation. The Netherlands has, according to the Köppen system, a temperate maritime climate with relatively mild summers (KNMI, 2016). There is no necessary need for mechanical ventilation in the Dutch buildings. Therefore, the ventilation system is found consistently. This research added another energy service instead of ventilation that affect the energy usage of Dutch buildings: the electronic appliances. These energy services can vary according to the normalization metrics described by Chung (2011).

Environmental characteristics

This research is based on the social care farms in the Netherlands. The Dutch climate is characterized by its unpredictability and can greatly differ in consecutive years (KNMI, 2016). The variation in weather conditions can lead to variations in the heating and cooling costs between years that affect the EPI. Due to the cold climate of the Netherlands (KNMI, 2016) is chosen only to examine the 'weather-normalized' value for space heating. This climate adjustment of the EPI could be made by degree-day[1] normalizations. The number of degree days per year can be obtained at a weather station in the vicinity of the social care farm.

Architectural characteristics

The main purpose of this research is to give insight into the energy performance of all social care farms (in the Netherlands). It is possible to compare more social care farms by taking the characteristics of the buildings into account. The three architectural variables that will be considered in this research are the age of the building, the total ground surface, and the total thermal transmission surface.

Occupational characteristics

Social care farms are businesses that simply has to deal with their opening times. The energy demand of a social care farm will be higher during the opening hours than when it is closed. In order to take these effects into account, the number of operational hours of the social care farms per year will be used as a variable in the EPI. The difference in occupancy of social care farms also affects the use of facilities that are present in de building. More people means more use of appliances and therefore a higher demand for energy. The yearly opening hours and the number of clients per year will be included as variables in the EPI formula.

Overview normalization metrics

The goal of the new Energy Performance Indicator is to provide a quick overview of a given performance parameter of the social care farms. By identifying a suitable EPI, the energy performance of a social care farm can be expressed. The basis EPI that will be used is as follows:

$$EPI = \frac{totaal\ annual\ energy\ use\ (MJ)}{floor\ surface\ (m^2)}$$

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[1] A unit used to determine the heating requirements of buildings, representing a fall of one degree below a specified average outdoor temperature (usually 18°C or 65°F) for one day.

Subsequently, the basis EPI is normalized to fit the specific social care farm characteristics. These are the heating degree days (HDD), the age of the building (Age), the floor surface (FS), the transmission surface (TS), the number of clients (Clients) and the yearly opening hours (YOH). The variables mentioned above were chosen to be the normalization metrics because they have an influence on the energy flows and/or processes associated with social care farm facilities (Figure 3).

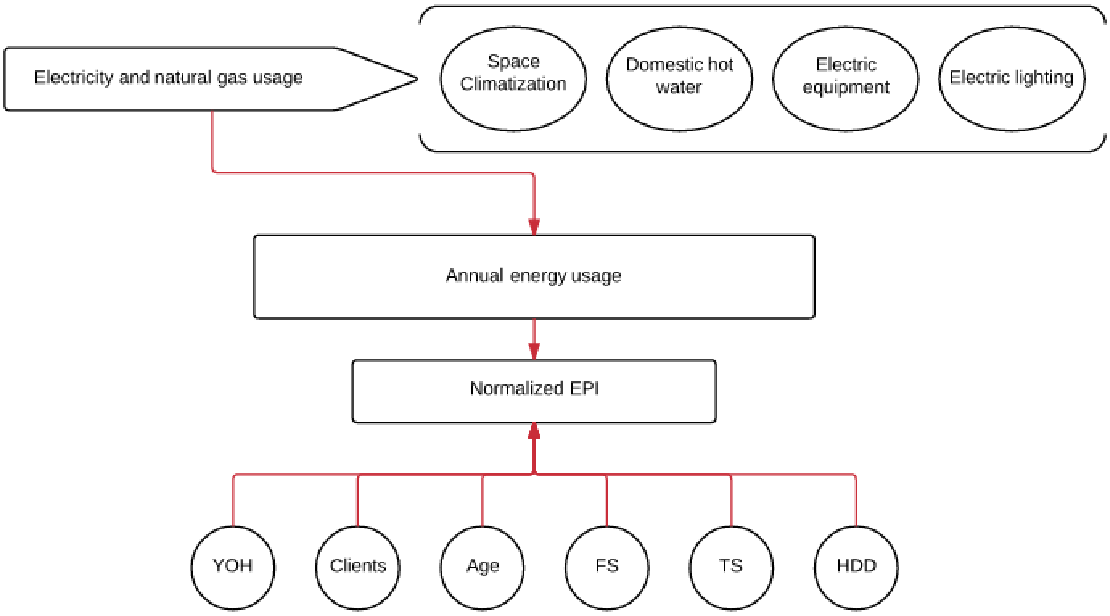

Figure 3: ontology representing the energy performance of a social care farm

2.3 DEVELOPMENT OF A NEW ENERGY CERTIFICATE

In this research is assumed that the typical distribution of energy usage among social care farms is affected by the selected set of explanatory variables mentioned in Section 2.2. After the determination of the explanatory variables and collecting the necessary data, the benchmarking process can start. The benchmarking process consists of three steps (Chung, Hui, & Miu Lam, 2006). First, a simple climate adjustment of the EPI by degree-day normalization. Second, regression model building to determine the relationship between the EPI and the selected explanatory variables. At least, the normalization of the explanatory variables to form a benchmark table. This research is based on the social care farms in the Netherlands. It can be assumed that the climate in this country is the same everywhere because of its small surface area. Therefore, step 1 will not play the main role but will be covered by the heating degree days as an explanatory variable to compare different years.

The second step is built a regression model. A regression model can be used to predict the future behavior by using the historical relationship between a dependent and an independent variable (PreMBA, 2016). When more than one independent variable is used, like in this case, it is called a multiple regression model.

The formula of the multiple regression model is as follows:

$$Y_i = b_0 + b_1 X_{1i} + .. + b_k X_{ki} + \varepsilon_i$$

Where:

Y_i = ith observation of the dependent variable Y, 1 = 1, 2, …, n
X_i = independent variables, j = 1, 2, …, k
X_{ij} = ith observation of the jth independent variable
b_0 = intercept term
b_j = slope coefficient for each of the independent variables
ε_i = error term for the ith observation
n = number of observations
k = number of independent variables

To build a regression model for the performance of social care farms with a data set of sample size n, Y will be the EPI and the independent variables can be found in Table 6. The missing data in Table 6 should be found in a new database for social care farms. The data for developing a new database can be obtained by surveys or an on-site study similar as performed in Chapter 3.

Table 6: explanatory variables of energy use in social care farms

Exogenous variable	Exogenous variable name	Minimum	Maximum	Mean ($\bar{X}_i$)	Standard deviation (S_i)
X_1	Yearly heating degree days	Data	Data	Data	Data
X_2	Building age	Data	Data	Data	Data
X_3	Internal floor surface	Data	Data	Data	Data
X_4	Internal transmission area	Data	Data	Data	Data
X_5	Yearly number of clients	Data	Data	Data	Data
X_6	Yearly operational hours	Data	Data	Data	Data

Normalized EPI

The exogenous variables are standardized according to the base levels (normal or mean standard). These base levels are used as a reference that reflects the standardized operation conditions. Chung et al. (2006) state that a best fitted multiple regression model for the social care farm EPI (MJ/m^2/year) can be constructed from this standardized data. It is assumed that the final model is of the form:

$$EPI = b_0 + \sum_{i=1}^{j} b_i \frac{x_{i\_}\bar{x}_i}{S_i} + \varepsilon$$

The formula above will be the basis for the normalization of the EPI for the significant factors. EPI_0 will be the observed Energy Performance Indicator (MJ/m^2/year) for a specific social care farm. The normalized EPI (EPI_{norm}) of this specific social care farm is then given by:

$$EPI_{norm} = EPI_0 + b_1 \frac{HDD\_\bar{x}_1}{S_1} + b_2 \frac{Age\_\bar{x}_2}{S_2} + b_3 \frac{FS\_\bar{x}_3}{S_3} + b_4 \frac{TS\_\bar{x}_4}{S_4} + b_5 \frac{Clients\_\bar{x}_5}{S_5} + b_6 \frac{YOH\_\bar{x}_6}{S_6}$$

The slope coefficient for each of the independent variable can be determined by using a software program such as Matlab or Microsoft Excel.

Labeling

It is assumed that after the gathering of information about social care farms, a data set of size n is available. If this data set includes sufficient buildings to create a reliable multi regression model, statistical analysis of the EPI_{norm} through the empirical cumulative distribution function (CDF) can show the energy position by using the percentile as an indicator (Robinson, 2004). For labeling, this research uses the normal distribution for sampling the data. The procedure of sampling from distributions is described in detail by Law and Kelton (2000), but due to the provided functions of software packages, there is no need to refer to underlying theory (Robinson, 2004).

The labeling of the EPIs will be equivalent to the assigning bands to energy performance classes (A-G). Therefore, a fitted scale for social care farms to this energy performance classes is required. The procedure to define the wide of the bands between classes is described by the standard deviation (σ). Figure 4 shows the new labeling method for social care farms based on the mean EPI_{norm} (μ) and the standard deviation (σ) of data set n.

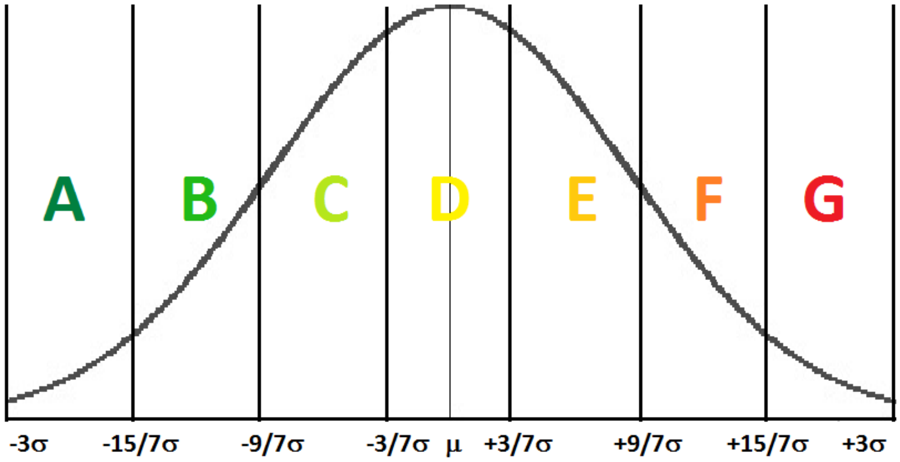

Figure 4: new labeling scale for labelling the energy performance social care farms

2.4 PRELIMINARY CONCLUSIONS

The energy performance of buildings in the Netherlands is largely linked to dwellings. The rules applicable to energy performance are primarily for new dwellings, therefore is for the existing buildings little urge to become more sustainable. In order to compare a different kind of buildings, a new specific benchmark is needed. In this study, this concerns a benchmark for social care farms. To make an impact on the sustainability of the care farms in the Netherlands, owners of social care farms should quickly and easily see how their social care farm perform against other social care farms. A convenient method to make the energy performance visible is through a label. This label works the same as the label in the residential sector, the energy performance of care farms can vary between G and A (where G is the worst performance and A is the best). Figure 5 displays the steps to go through in this labeling process.

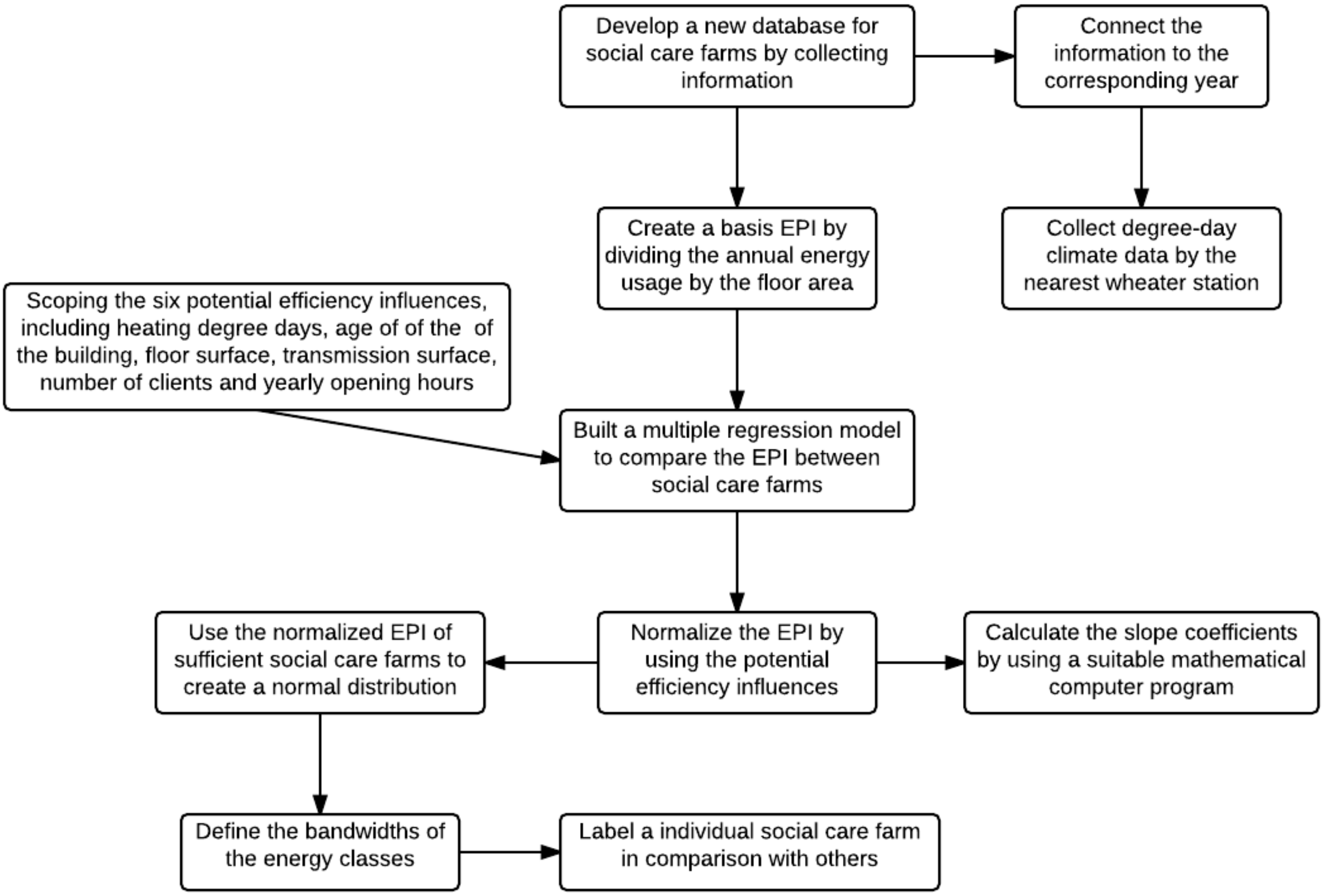

Figure 5: the detailed implementation procedure of the developed labeling approach for social care farms

3 ENERGY USE CASE STUDY

This chapter will provide insights into the annual energy use of a social care farm. These insights are based on a case study of social care farm Alldrik from Markelo. The complex of a social care farm includes several functions that need to be defined. The main difference between a social care farm and other day-cares is the split between the dwelling and the work area. Figure 6 shows the floor plan of the current status of social care farm Alldrik. Five different buildings can be distinguished: the dwelling, the meeting area, the shed with storage/workshop/changing room, the nature store, and the stables. In Appendix A, the detailed floor plans and photographs of the different buildings are made visible.

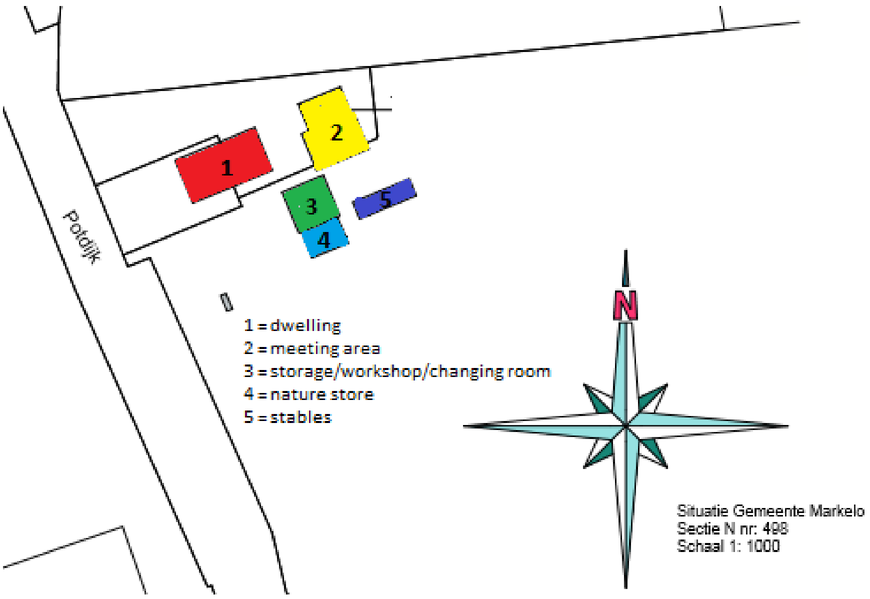

Figure 6: Floor plan Alldrik

To identify the energy usage of a social care farm, a distinction is made between the residential area (1) and the buildings related to the social care farm (2,3,4 and 5). All the buildings are connected to the same gas, water network, and electricity power grid. Therefore, Alldrik has one fuse box, located in the dwelling, for all the facilities within the complex. The fuse box consists of a double meter[2] for electricity, a natural gas meter and a water meter.

This chapter will provide the first information for the benchmarking process of social care farms regarding energy usage. The following topics will be covered: An introduction to the known figures of the Dutch energy usage, the annual theoretical energy use of the heated buildings based on computer program Vabi Elements, the annual actual energy use based on energy bills and meter readings on site.

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[2] Reduced night tariffs are available if the property has a double meter. The reduced tariff is available between 23:00 – 07:00 and at weekends between 23:00 Friday until 07:00 Monday.

3.1 INTRODUCTION ENERGY USAGE

In 2015, the worldwide annual natural gas usage was estimated at $3468,6 \cdot 10^9$ m^3 (BP, 2016). This means, based on the current population (Worldometers, 2016), an average annual natural gas usage of 471,0 m^3 per capita. A major difference appears, comparing this figure with Eurasia (1350,4 m^3 per capita). In the Netherlands, this is even more with 1881,5 m^3 annual natural gas use per capita. In Figure 7 a similar comparison is made for the electricity use by the World DataBank (2016). In 2013, the electric power usage per Dutch capita was 13,01% higher than an average European citizen. Worldwide, the average electric power usage of the Dutch citizen is 119,72% higher.

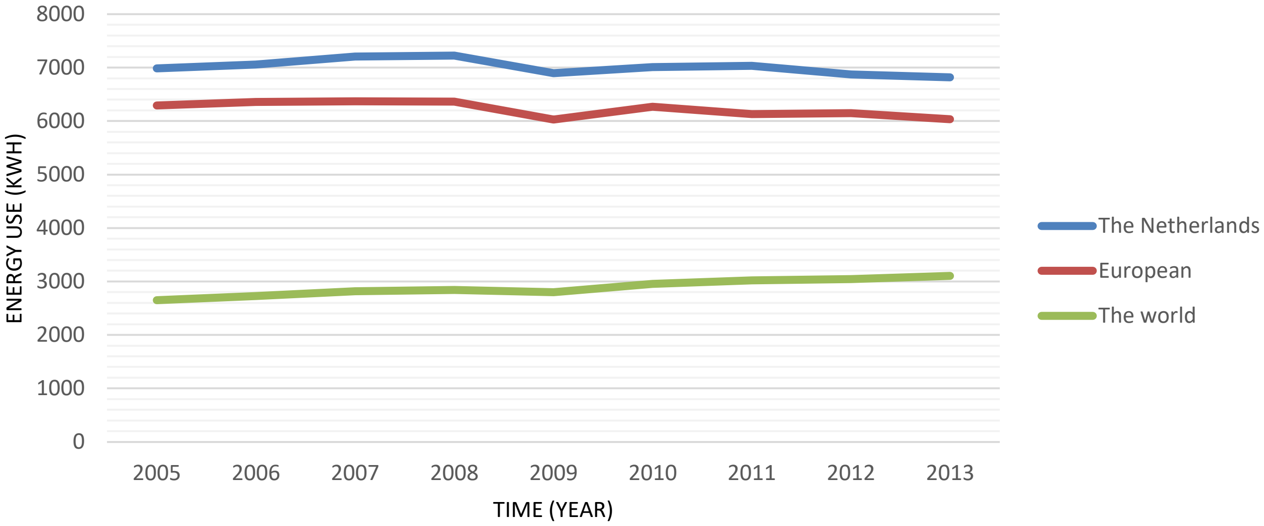

Figure 7: electric power usage (kWh per capita) (The World Bank, 2016)

By analyzing both the natural gas and electric power usage, it can be concluded that the energy usage of the Netherlands is far above average. Bernstein (2003) state that there are main factors that affect the intensity of energy usage. To determine the changes, the factors have to be measurable. Bernstein examined the changes in energy intensity for the residential, commercial, industrial, and transportation sectors in the period between 1977-1999. As a result, he could formulate eight different factors that may explain the difference:

- Energy prices
- Composition of an economic sector's output
- Capacity utilization
- Capital investment and new construction
- Population and demographics
- Climate
- Technological innovation
- Energy policies and actions of national, state, and local government

Although the causes may be understood, it is still difficult to apply. Statistician van Mosseveld (2003) explains that scientists regularly compare data from different countries without the exact background information. This enables them to draw conclusions that are not true, while the data is correct. In the continuation of this research, only national data will be used to examine the annual energy usage.

Figures of the energy usage of households in the Netherlands

In the Netherlands, the majority of the dwellings receive their energy through connections to the natural gas network and the electricity power grid. The energy service companies obtain a lot of information that can be used for a national database. Statistical authorities like CBS, RVO and Rijkswaterstaat (RWS) combine these data to provide insight into the national annual energy usage. Based on the database of RWS (Rijkswaterstaat, 2016) an accurate estimation of the annual energy use of dwellings in the

Netherlands can be made. In 2015, the total natural gas use of dwellings was 9514,8·10^6 m^3. The total electric power use of dwellings, in the same year, was 22574,8·10^6 kWh. Figure 8 shows the annual energy usage of dwellings during the period from 2010 to 2015.

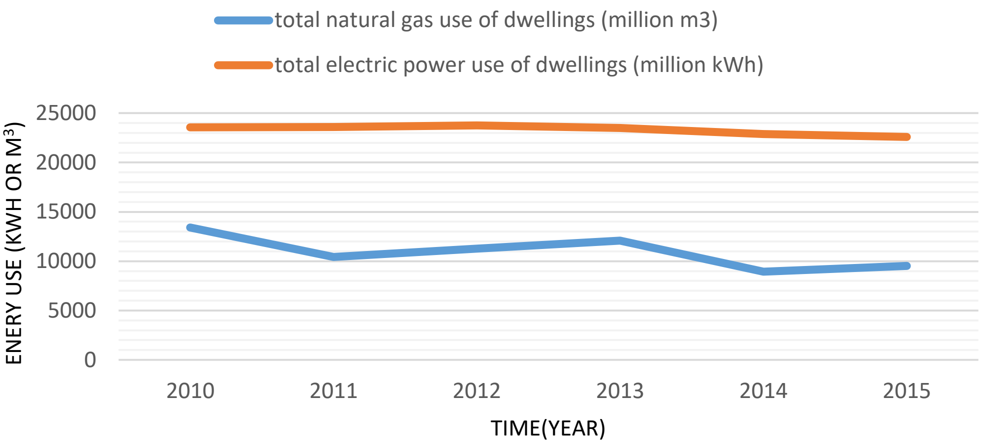

Figure 8: total annual energy use of dwellings in the Netherlands (Rijkswaterstaat, 2016)

The total amount of energy use of dwellings cannot make statements about an individual dwelling. The RVO has formulated six different reference dwellings (RVO, 2016) so that a dwelling can group by equivalent type. The following type of dwellings are chosen:

- Spacious house
- Corner house
- Semi-detached house
- Detached house
- Gallery complex
- Apartment complex

In this research, only the detached houses will be included. Due to the size of farms and the space required for their functions almost all the farm dwellings in the Netherland can be considered as detached houses. The average energy use per detached dwelling can give insight into the energy use of the housing accommodation of a social care farm (Figure 9).

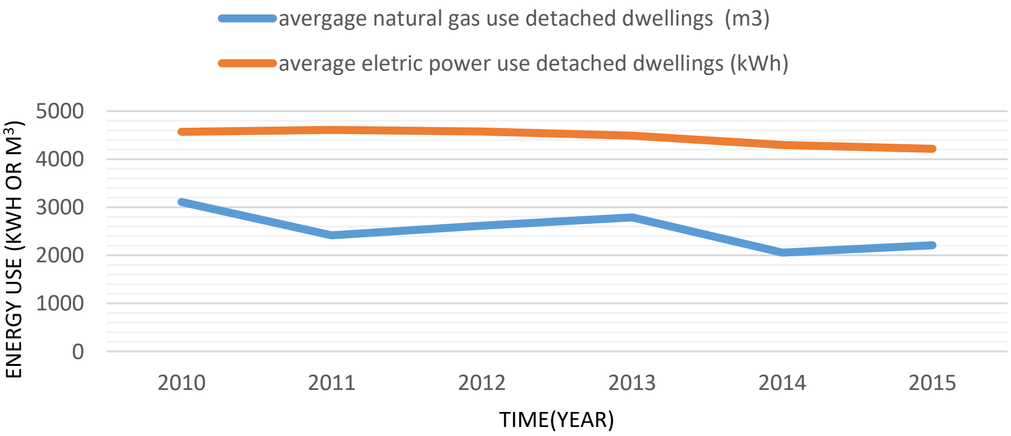

Figure 9: average annual energy usage detached dwellings in the Netherlands (Rijkswaterstaat, 2016)

The care farm that is used for the case study is located in the municipality of Hof van Twente. In the case study should be taken into account that the annual energy use in Hof van Twente is above the national average (1,8% natural gas and 3,1% electric power). The average annual natural gas use by detached dwellings in the municipality of Hof van Twente is 34,9·10^2 m^3 and the average electric power usage is 52,3·10^2 kWh in 2015 (Rijkswaterstaat, 2016). The surface of a detached dwelling has an average of 164

m^2 (RVO, 2016). The annual energy footprint for detached dwellings in the municipality of Hof van Twente is 21,3 m^3/m^2 natural gas and 31,9 kWh/m^2.

Figures on the energy breakdown in the Netherlands

In 2011, a total energy balance in PJ was made for the energy use of natural gas and electric power per sector in the Netherlands (Provoost, Santen, & Overgoor, 2012). The total (net) energy usage was 1743 PJ and consisted of 82,3% natural gas and 17,7% electric power. The energy usage is divided into different sectors: the energy sector, industry, transport, households, agriculture fisheries, and services. In Figure 10 is shown how the energy use breakdown is divided between the different sectors in 2011.

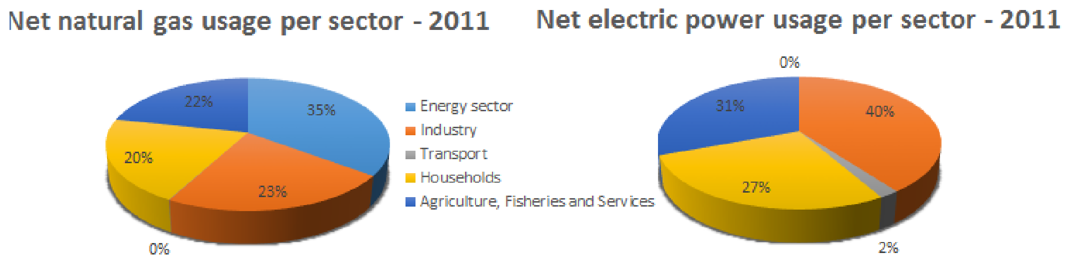

Figure 10: net energy usage per sector in the Netherlands, 2011 (Provoost, Santen, & Overgoor, 2012)

As can be seen in Figure 10, households are responsible for 21,7% of the total energy usage in the Netherlands. Therefore, it is import to gain more insight into the energy breakdown of households. The energy usage of dwellings can be divided into different categories. This disaggregation of the energy usage provides information on what systems or appliance have an influence on the total energy use.

A study about the efficiently of the energy usage of households in the Netherlands confirmed that households use 20% of the total Dutch energy in 2011 (Hieminga, Saving Energy in the Netherlands, 2003). This study resulted in an estimation of the breakdown of energy use by households (Figure 11).

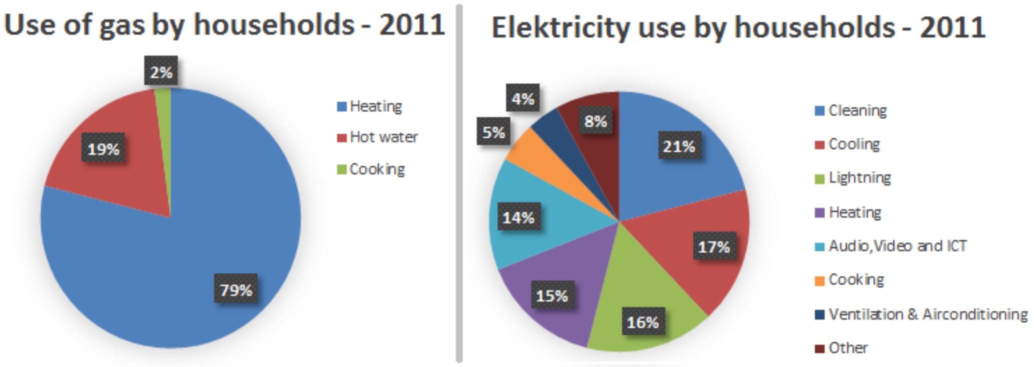

Figure 11: energy breakdown households in the Netherlands, 2011 (Hieminga, 2003)

The study of Hieminga (2003) will be used as a basis to determine the natural gas breakdown of the dwelling. The dwelling of Alldrik is detached and located in the municipality of Hof van Twente. The average annual natural gas usage by detached dwellings in the municipality of Hof van Twente is 2260 m^3 (Rijkswaterstaat, 2016). Based on the known figures, it is assumed that the natural gas usage for DHW = $\frac{2260\ x\ 0,19}{52}$ = 8,36 m^3 per week and the natural gas usage for cooking = $\frac{2260\ x\ 0,02}{52}$ = 0,87 m^3 per week. This information is needed in respect of private circumstances later in this research.

3.2 ANNUAL THEORETICAL ENERGY USE

In Section 2.1, the EPG is mentioned as the determination method for creating an EPC calculation. The software programs that are certified for calculating the EPC, which means that a certifying authority ensures the quality in accordance tot the BRL9501, uses licenses. The only program of which a license is available at the University of Twente is calculation program Vabi Elements EPG. The Buildings Energy Performance Standard (EPG) in Vabi Elements is an umbrella assay method for the energy performance of both dwellings and utility buildings. The EPG is applicable to all construction applications from July 1, 2012. The complex of Alldrik is not new and therefore is an EPC not obligated. However, the calculated EPC is used to gain an understanding of the characteristic energy use of the buildings. In this research, two buildings are eligible for the EPC calculation by having a heating system: the meeting area and the dwelling. Information about the building is required in order to compose an acceptable EPC calculation. Information about two main categories is considered: structural characteristics and the applied systems.

The applied systems are the systems present in a building, have an influence on the energy demand. Vabi Elements covers four different systems: heating, domestic hot water, lighting, and ventilation.

Architectural characteristics

The main components that are understood by architectural characteristics are the thermal envelope constructions and interior constructions. The thermal envelope is the main insulating layer of a building, which border to the outside air. This thermal envelope includes all outside walls, outside doors, windows, roof and the ground floor. The interior constructions are the constructions within the thermal envelope. The layers of which these components exist determine the insulation performance of the thermal shell. The dimensions of a building are used to determine the energy budget. The energy budget determines how much energy a building should use based on the size. Further, the dimensions are needed to define the surfaces of components of the thermal shell (the total thermal transmission surface).

The energy performance is linked to the thermal flows in a building. The heat loss through a regular construction (a floor to the basement or a slab on ground, an external wall, a roof or ceiling) can be characterized by the thermal heat loss coefficient (U-value). In order to make a distinguish between different types of insulation, the R-value is used. The R-value is the thermal resistance coefficient of a material layer and is determined by the insulation value and thickness of the material.

By January 1, 2015 are the minimum requirements for the thermal resistance (R_c-values) of the Dutch Building Code compulsory 2012 increased. The following minimum R_c-values for new buildings are mandatory (NEN, 2014):

- Floors $R_c \geq 3{,}5\ m^2\ K\ W^{-1}$
- Walls $R_c \geq 4{,}5\ m^2\ K\ W^{-1}$
- Roofs $R_c \geq 6{,}0\ m^2\ K\ W^{-1}$

Table 7 shows the thickness of insulation based on the material (Feist, 2006) that is needed to achieve the R_c-values of an exterior construction. From this table, it can be seen that only a reasonable thickness is available if a quite good insulation material is used.

Table 7: thickness of insulation material per external part

Material	Heat-conductivity (W m^{-1} K^{-1})	Thickness (m) needed to meet R_c = 3,5 m^2 K W^{-1}	Thickness (m) needed to meet R_c = 4,5 m^2 K W^{-1}	Thickness (m) needed to meet R_c = 6,0 m^2 K W^{-1}
Concrete B50	2,100	7,35	9,46	12,57
Solid brick	0,800	2,80	3,60	4,79
Hollow brick	0,400	1,40	1,80	2,40
Wood	0,130	0,46	0,59	0,78
Porous concrete	0,110	0,39	0,50	0,66
Straw	0,055	0,19	0,25	0,33
Typical insulation material	0,040	0,14	0,18	0,24
Highly insulation material	0,025	0,09	0,11	0,15
Nanoporous ‘’super insulation’’	0,015	0,053	0,068	0,090
Vacuum-insulation (silica)	0,008	0,028	0,036	0,048
Vacuum-insulation (high vacuum)	0,002	0,007	0,009	0,012

It is also important to reduce the heat loss through glazing. The insulating value of glass is usually described by the U-value. The U-value indicates the amount of heat which is lost through the glass. The lower the U-value, the less heat is lost, and therefore better insulating properties of the glass. Windows, doors and window frames need to comply with an U-value of 1,65 W/m^2K at maximum. Table 8 shows the different between the types of glass that can be used in a building.

Table 8: U-value/R-value per type of glazing (Luchtdicht bouwen, 2016)

Glass type	U-value (W/m^2K)	R-Value (m^2k/W)
Single glazing	5,7	0,175
Double glazing	± 3	0,333
HR glazing	1,6 – 2,0	0,625 – 0,5
HR+ glazing	1,2 – 1,6	0,833 – 0,625
HR++ glazing	< 1,2	> 0,833

Applied systems

The comfort of a building depends on the climate in the area where it stands. In general, the natural environment does not provide the desired interior temperature in a building. Traditionally, the occupant regulates a pleasant internal temperature by heating in the cold winter and cooling in the hot summer. Nowadays, thermodynamic, mechanical and electronic systems facilitate a comfortable climate.

The systems that are present in a building have an influence on the energy demand. Vabi Elements covers four different systems: heating, domestic hot water, lighting, and ventilation.

3.2.1 MEETING AREA

Architectural characteristics

The meeting area is a detached building with a pointed roof and is considered as an utility building with a gathering function. Information about the constructions is needed within the boundaries of the EPC calculation. In Table 9, all the R_c-values and surfaces of the constructions of the meeting area are mapped. The detailed information of these constructions can be found in Appendix E. The heat loss through thermal bridges is determined with the flat method. The calculated perimeter with the flat method is 41,96 meter.

Table 9: construction characteristics meeting area Alldrik

Construction element	R_c-value ($m^2 \cdot K/W$)	U-value (glass) ($W/(m^2 \cdot K)$)	Surface (m^2)
Ground floor	2,51	(-)	100,89
Roof	2,50	(-)	124,59
External Façade	4,02	(-)	108,83
Windows	(-)	1,10	15,53
Exterior doors	0,41	(-)	3,83
Interior doors	0,41	(-)	5,46
Panels	1,55	(-)	6,51
Interior Walls	3,63	(-)	30,30
Interior Floors	3,63	(-)	14,28

Geometry

The geometry of a building is necessary to determine the energy budget for the EPC calculation. The geometry of the meeting area is obtained through construction drawings and measurements. The dimensions of the different rooms can be found in Table 10 and are made visible in Figure 12.

Table 10: dimensions rooms meeting area Alldrik

Room type	Colour	Volume (m^3)	Floor area (m^2)
Fuse box	Blue	1,923	0,805
Hall	Purple	16,795	6,998
Toilet	Green	15,542	6,476
Meeting area	Red	135,550	39,278
Meeting area with cooking appliance	Orange	163,354	45,705
Technical room	Yellow	15,007	14,279

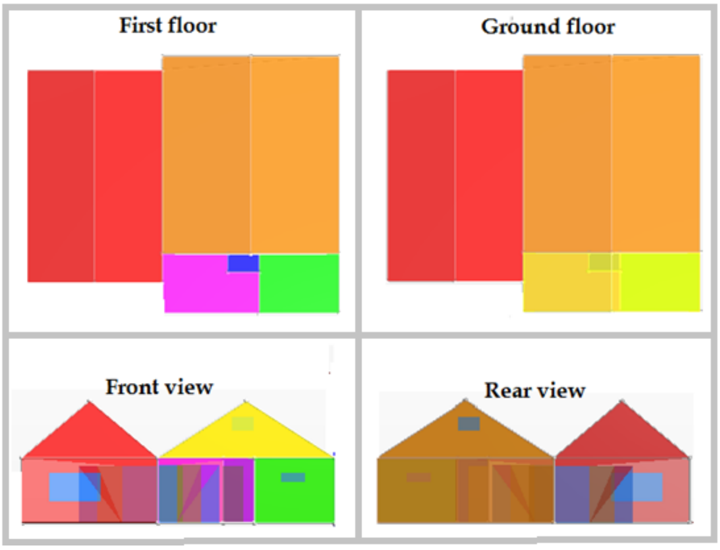

Figure 12: visual display of the rooms in the meeting area

Space Heating & domestic hot water

The meeting area has one general heating system, a HR-107 boiler with radiators for the heat release. The specifications of the boiler can be found in Appendix G. The boiler also provides the distribution of the domestic hot water in the kitchen. The tap for domestic hot water is within 3 meters of the generation unit.

Lighting

The existing lighting in the meeting area can be found in Table 24. The lighting is manually operated with switch buttons on the wall. For the calculation in Vabi Elements, Table 24 is used to determine the lighting power.

Ventilation

The Dutch Practice Guideline NPR 1088 distinct in the Netherlands four types of ventilation systems:

- System A: natural supply and natural exhaust
- System B: mechanical supply and natural exhaust
- System C: natural supply and mechanical exhaust
- System D: mechanical supply and exhaust

System A, the mechanical supply and natural exhaust, is used in the meeting area. However, the toilet has a system C ventilation driven by a direct current motor. The type duct is a galvanized steel spiro duct (125 mm) with airtightness class D.

3.2.2 DWELLING

Architectural characteristics

The dwelling is a detached building with a pointed roof and is considered as a residential building with a residential function. Information about the constructions is needed within the boundaries of the EPC calculation. In Table 11, all the R_c-values and surfaces of the constructions of the meeting area are mapped. The detailed information of these constructions can be found in Appendix F. The heat loss through thermal bridges is determined with the flat method. The calculated perimeter with the flat method is 44,66 meter.

Table 11: construction characteristics dwelling Alldrik

Construction element	R_c-value ($m^2 \cdot K/W$)	U-value (glass) ($W/(m^2 \cdot K)$)	Surface (m^2)
Ground floor	2,53	(-)	110,78
Roof	3,05	(-)	152,24
External Façade	2,57	(-)	116,32
Windows	(-)	1,10	26,64
Exterior doors	0,24	(-)	3,78
Interior doors	0,40	(-)	21,06
Interior Walls	0,65	(-)	187,69
Interior Floors	2,57	(-)	181,90

Geometry

Just like the meeting area, it is necessary to determine the energy budget for the EPC calculation. The geometry of the dwelling is obtained through construction drawings and measurements on site. The dimensions of the different rooms can be found in Table 12 and are made visible in Figure 13.

Table 12: dimensions rooms dwelling Alldrik

Room type	Colour	Volume (m³)	Floor area (m²)
Hall	Purple	45,648	21,897
Toilet	Pink	4,856	2,023
Bathroom	Red	54,888	24,260
living with a cooking appliance	Orange	148,159	61,265
Storage	Yellow	35,498	73,753
Bedroom	Blue	174,574	86,627
Workroom	green	17,976	7,194

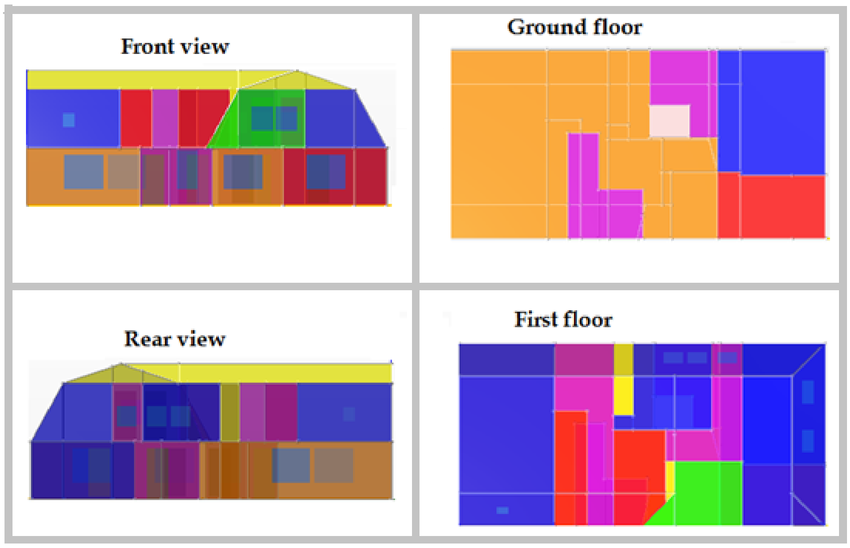

Figure 13: visual display of the rooms in the dwelling Alldrik

Space heating & domestic hot water

The space heating is provided by a HR-107 boiler (Appendix G), which distributed the heat through HT radiators by the inner walls or windows and a distributed by a provides HR 107 boiler (Appendix), which heat the house through HT radiators for the inner wall or window and a underfloor space heating on the ground floor. The boiler is placed within the limits of the calculation EPC and is powered by natural gas. The domestic hot water is provided by the same boiler and has comfort class CW-4. There are several taps within a radius of 3 meters.

Lighting

The energy that is required for lighting power in the dwelling is calculated by the flat method. This is decided because of the private circumstances and time boundaries. Therefore, no clear light schedule could be made for the dwelling.

Ventilation

The main ventilation in the dwelling is performed by system A, the mechanical supply and natural exhaust. However, small fans are applied in the kitchen, bathrooms, and toilets. These ventilation points will be ignored to simplify the calculation in Vabi Elements.

Meeting area

The theoretical annual energy usage of the meeting area is calculated by Vabi and is shown in Table 13. The total characteristics energy usage is higher than the admissible characteristic energy usage. Therefore, it does not suffice.

Table 13: annual energy usage meeting area according to Vabi Elements

Total ground surface	Ag;tot	98,21 m^2
Total thermal transmission surface	Aloss	311,59 m^2
Total characteristic energy usage	EPtot	51216 MJ
Admissible characteristic energy usage	EP;adm;tot	45716 MJ
Specific energy performance		522 MJ/m^2Ag
Total/admissible	**EPtot/EP;adm;tot**	**1,12 does not suffice**

The EPC requirement for a building with the gathering function is 1,10 (Table 5). As shown in Table 14, the EPC of the meeting area of 1,23 does not meet the EPC requirement for a building with a gathering function. Therefore, improvements can be made to achieve the wanted EPC.

Table 14: energy performance meeting area according to Vabi Elements

Functional use	Ag (m^2)	EPC requirement	EPC	EPC meets?	Energy Index	Energy Label
Gathering function	98,21	1,10	1,23	no	0,89	A

Dwelling

The theoretical annual energy usage of the dwelling calculated can be found in Table 15. Just like the meeting area does the total characteristic energy usage divided by the admissible characteristic energy usage not suffice.

Table 15: annual energy usage dwelling according to Vabi Elements

Total ground surface	Ag;tot	238,37 m^2
Total thermal transmission surface	Aloss	350,92 m^2
Total characteristic energy usage	EPtot	118757 MJ
Admissible characteristic energy usage	EP;adm;tot	49597 MJ
Specific energy performance		498 MJ/m^2Ag
Total/admissible	**EPtot/EP;adm;tot**	**2,39 does not suffice**

The EPC requirement for a building with the residential function is 0,40 (Table 5). As shown in Table 16, the EPC of the meeting area of 0,96 does not meet the EPC requirement for a building with a residential function. Therefore, improvements can also be made for the dwelling to achieve the wanted EPC.

Table 16: energy performance dwelling according to Vabi Elements

Functional use	Ag (m^2)	EPC requirement	EPC	EPC meets?	Energy Index	Energy Label
Residential function	238,37	0,40	0,96	no	1,42	C

Breakdown of the theoretical energy usage

The breakdown of the energy usage in both the meeting area and dwelling can help to find the point to enhance. The breakdown of both buildings has been made visible in Figure 14.

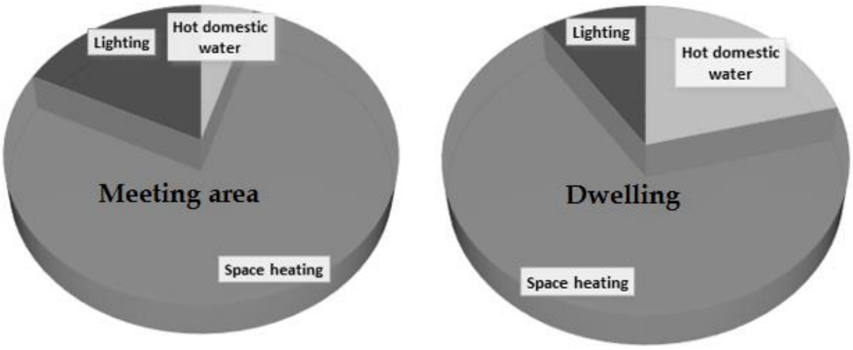

Figure 14: breakdown energy usage heated buildings according to Vabi Elements

3.3 ANNUAL ACTUAL ENERGY USE

In this section, insights will be given into the actual energy use of social care farm Alldrik. Residential energy usage is measured by utility companies, utilizing the analog (in this case) meters installed in the dwelling. This data is recorded by the utility company, resulting in a bill for the annual energy. In the case of analog meters, energy usage can be checked by keeping track of the meter readings for a period of time. In addition, keeping track of the meter readings can help to be more aware of the energy use behavior.

When introducing the research in September 2016 at Alldrik, the owners were requested to observe the daily energy use for creating a new database. Therefore, more data about the actual energy use was available. On location, the meter readings were daily observed at the same time so that the data is more accurate. In this research, an overview of the energy use during one week is made. This overview is based on a full week in operation. This means a weekly cycle without leave, public holidays, absence etc. This is decided in order to better understand the use of a complex with the social care farm function. The weekly cycle of social care farm Alldrik can be found in Table 17.

Table 17: the weekly cycle of social care farm Alldrik

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Closed	09:00-16:30	09:00–16:30	09:30-16:30	09:30-16:30	10:00-16:30	Closed

The following assumptions have been made during this entire week cycle:

- The facilities in the dwelling are not used during the opening hours of Alldrik.
- Outside the opening hours of Alldrik is not made use of the facilities of the social care farm.
- The heating of the social care farm is at night mode (13 °C) outside the opening hours of Alldrik.
- There is made use of the dwelling outside the opening hours of social care farm Alldrik.

3.3.1 ENERGY BILLS

The energy supplier of social care farm Alldrik is Innova Energie BV. By means of the annual energy bill is it possible to make an estimation of the annual energy usage. The complex Alldrik underwent significant renovations in November 2014. Therefore, it is decided to look only at the energy bills after this conversion. The current situation is similar to the situation of the used energy bills so that the energy bills can give an appropriate indication of the annual energy usage.

Energy usage 2014-2015

The usage of electricity and natural gas in 2014-2015 is based on a time period from December 8, 2014 to November 12, 2015 (339 days). Detailed information about this period can be found in Appendix B. The electricity use is divided into an off-peak use and normal use. The off-peak use is in operation between 23:00 pm and 09:00 am and over the weekend. The normal use is in operation in all other cases. Table 18 shows an annual electricity usage of 11979 kWh and an annual natural gas use of 2868 m^3.

Table 18: annual electricity and natural gas usage 2014-2015

	Off-peak (1)	**Normal (2)**
Electricity (green)	4859 kWh	7120 kWh
Natural gas (gray)	(-)	2868 m^3

Energy usage 2015-2016

The usage of electricity and natural gas in 2015-2016 is based on the period between November 12, 2015 to October 17, 2016 (340 days). Detailed information about this period can also be found in Appendix B. Table 19 shows an annual electricity usage of 10070 kWh and an annual natural gas usage of 2583 m^3.

Table 19: annual electricity and natural gas usage 2015-2016

	Off-peak (1)	**Normal (2)**
Electricity (green)	4083 kWh	5987 kWh
Natural gas (gray)	(-)	2583 m^3

The annual energy usage according to the energy bills

The first thing to notice, when comparing both energy bills, is the reduction of the energy usage. The total electricity usage has decreased by 15,94% (off-peak 15,97% and normal 15,91%) compared with the previous year. The total natural gas usage has decreased by 9,94%. Since the periods of the measurements in the energy bills have much overlapping. A good reason for this reduction of electricity usage could be the replacement of the normal lighting to LEDs in 2015.

3.3.2 ANALYSIS OF THE METER READINGS

In this research, two different data sets are collected and evaluated. The first series is collected in the period between September 5 and November 14 and the second series between November 17 and December 22 (Appendix C). Except for the fact that both series contain data from other months, the main dissimilarity is the time of measurement. The second series is measured every day at exactly 09:00 o'clock, while within the first series the measurement time varies. Therefore, it is assumed that the second series is more accurate. In this case, the water consumption is included to enlarge the database for social care farms. It is possible that the water consumption might be relevant for future studies about social care farms.

Frist, the series in the period September 5 till November 14 will be evaluated. In this period, the average usage per day is measured. The annual uses can be determined by comparing the mean in time. This cumulative mean will show the variance of energy/water use during the period. Figure 15 shows that the cumulative mean of the electricity usage and water consumption is well-nigh constant, but de cumulative of natural gas use is growing as it reaches the colder months. Therefore, the second series should give evidence that the electricity usage and water consumption is constant and give a method to determine the annual natural gas usage.

In the second series, the more accurate one is made a similar evaluation. In Figure 16 can be seen that cumulative means of the electricity usage and water consumption still are practically constant. Therefore, with the collected data in this time frame, it is assumed that the cumulative mean can be used for determination of annual the electricity usage and water consumption (Table 20). On the other hand, the natural gas usage has not a constant cumulative mean. However, Figure 16 shows a constant mean in the month December. In this research, it will be assumed, with the available data, that the cumulative mean of natural gas usage is constant per month. The difference in usage per month should be corrected by means of degree days.

Table 20: annual electricity usage and water consumption Alldrik, 2016

Period 17 Nov – 22 Dec	**Electricity 1: low**	**Electricity 2: normal**	**Electricity total**	**Water**
Mean per day	7,3 kWh	11,3 kWh	18,6 kWh	0,67 m^3
Annual usage (365 days)	2664,5 kWh	4124,5 kWh	6789 kWh	244,5 m^3

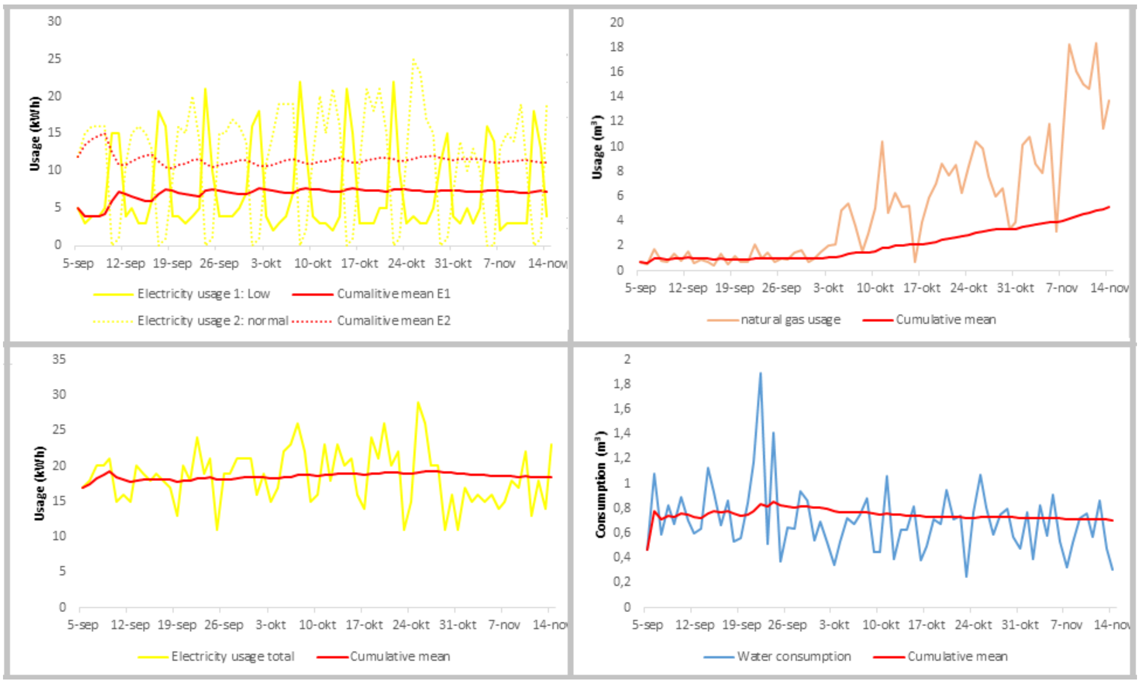

Figure 15: average use Alldrik per day during September 5 - November 14, 2016

Figure 16: average use Alldrik per day during November 17 - December 22, 2016

Developing reference for the natural gas usage per month

The basic principle of a degree-day is that if the average outside temperature, in the space of 24 hours, is higher than the outside temperature no natural gas is used. However, a lower inside temperature will cause heating and degree days should be counted. In General, the degree days calculation of 18 °C is taken as the value for the mean indoor temperature (Wang, Shen, Alp, & Barry, 2015).

In addition to the outside temperature, there are even more weather conditions which affect the thermostat. for example, the warmth of the sun on the building. To minimize the impact of those changes on the calculations, the degree days are multiplied by a seasonal weighting factor. As a result, the weighted degree days per year. The weighting factor during the year is as follows (KMNI, 2016):

- April - September: 0,8
- March – October: 1,0
- November – February: 1,1

The degree-day climate information is gathered from local weather stations. In this case, the nearest weather station is Twenthe in the Netherlands (KMNI, 2016). In the second data series (Figure 16) was made clear that the cumulative mean of the natural gas usage is constant in December. Therefore, the month December will be the reference month to normalize the other months in 2016. This reference can be used to create a comparison scenario for the natural gas usage between different years. The behavior of the natural gas usage according to the degree days can be found in Figure 17. Table 21 shows the reference table for the natural gas usage per month and the total natural gas usage in 2016.

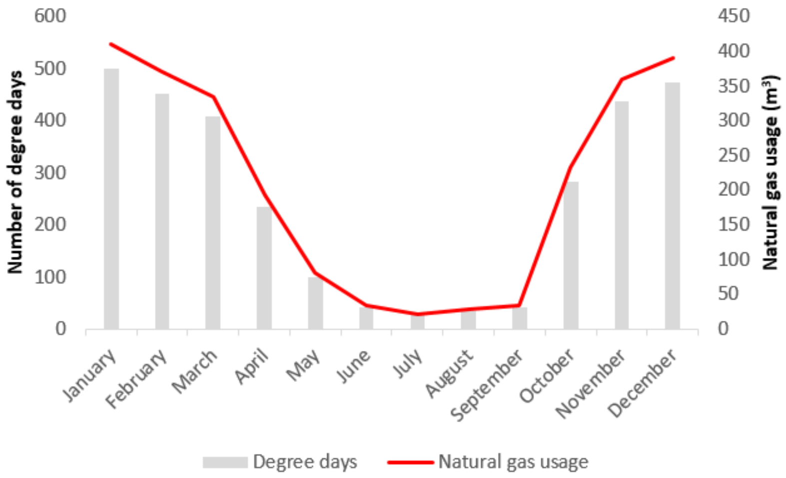

Figure 17: behavior of the natural gas usage based on the degree days, 2016

Table 21: reference table natural gas usage based on the degree days, 2016

Month	Degree days (2016)	Natural gas usage (m³)
January	499	410,4561
February	451	370,9734
March	407	334,7809
April	235	193,301
May	98	80,61062
June	41	33,72485
July	26	21,38649
August	35	28,78951
September	41	33,72485
October	283	232,7837
November	436	358,635
December	474	389,8922
Total	**3026**	**2489,059**

The reference table is validated by historical data validation. Data of the natural gas usage is already collected by the meter readings in the period between September 5 - November 14 and November 17 - December 22. Therefore, this data will be used to determine whether the reference model behaves like the actual natural gas use. The existed historical data, the energy bills, will be used to compare the annual natural gas usage in the last two years with the annual natural gas usage in the reference table. Table 22 shows the validation of the reference table with the historical data. As a result, it is visible that the reference table behaves similarly to the historical data. Therefore, it is assumed that the table is valid enough to be used as a reference for the natural gas usage per month.

Table 22: historical data validation reference table natural gas usage

	5-31 Sep	1-30 Oct	1-14 Nov	17-30 Nov	1-22 Dec	Annual
Data series (Sep 5-Nov 14)	26,53 m^3	197,18 m^3	170,54 m^3	N.A.	N.A.	N.A.
Data series (Nov 14-Dec 22)	N.A.	N.A.	N.A.	173, 94 m^3	302,68 m^3	N.A
Energy bill (2014-2015)	N.A.	N.A.	N.A.	N.A.	N.A.	2868 m^3
Energy bill (2015-2016)	N.A.	N.A.	N.A.	N.A.	N.A.	2583 m^3
Reference table (2016-2017)	27,20 m^3	232,78 m^3	167, 36 m^3	167,36 m^3	276,70 m^3	2490 m^3
Δ Deviation reference table	2,53%	18,05%	1,86 %	3,78 %	8,58%	8,64%

4 IDENTIFICATION OF POTENTIAL ENERGY EFFICIENCY MEASURES

This chapter will introduce potential energy efficiency measure to reduce the annual energy demand for a particular social care farm.

4.1 ENERGY USE BREAKDOWN

In this section, the breakdown of the uses will be clarified by means of balances. Energy is never lost according to the law of conservation of energy, the energy/water balances can give insight into where the energy/water is delivered. In the case study, the meter readings are precisely observed at the same time during an operational week as described in Table 17. The meter readings are observed in the period between Thursday, November 17th at 09:00 am and Thursday, November 24th at 09:00 am. In this period, a distinction is made in the energy/water usage inside and outside the opening hours of Alldrik. The measurement times are based on the opening and closing times of Alldrik (Table 17) and can be found in Appendix C. Table 23 shows the uses in the week of measurement and Figure 18 shows the breakdown between the use inside and outside the opening hours of Alldrik. It is assumed that the week cycle is constant enough to give insight into the annual energy usage. This assumption can be made because every operational week in the year is composed similarly.

Table 23: overview energy usage between 11-15 to 11-24 (2016)

Total electricity use in a week	120 kWh
Electricity usage Alldrik in a week	35 kWh
Total natural gas use in a week	66,977 m^3
Natural gas usage Alldrik in a week	21,123 m^3
Total water consumption in a week	4,395 m^3
Water consumption Alldrik in a week	2,096 m^3

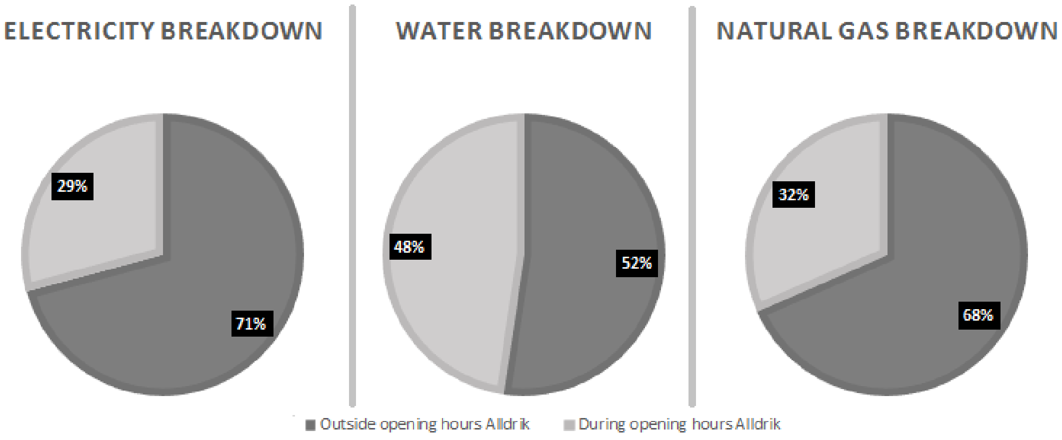

Figure 18: breakdown energy and water usage between 11-17 to 11-24 (2016)

4.1.1 ELECTRICITY USAGE BREAKDOWN

The electricity usage of Alldrik can be divided into two different categories: lighting and electrical appliances. The energy balance for electricity usage is as follows:

$$E_{electricity} = E_{lighting} + E_{appliances} + E_{miscellaneous}$$

Lighting

The lighting scheme of the social care farm is intensively studied for a week during the opening hours of Alldrik. Every half hour during the openings times of Alldrik is checked if the present lights were on or off. All the lighting of Alldrik can be found in Table 24. The lighting in the disabled toilet is based on the number of toilet visits in a week. It is assumed that a visit to the toilet takes on average 2 minutes. During the test week, there were 106 restroom visits (see paragraph water consumption Alldrik). The total amount of lighting (summarized in Table 24) can be used to determine the total energy needed for lighting during a week cycle. The total electric power usage for lighting during one week during the opening hours of the social care farm is 7,74 kWh according to the lighting schedule.

Table 24: overview electric power usage lighting Alldrik

	Type	#	Power	Lightning hours per week (total)	kWh
Meeting area right	Luminaire	4	28 W	130	3,640
	E14 LED Filament candle light	18	2 W	234	0,468
Meeting area Left	Luminaire	2	28 W	17	0,476
	E14 LED Filament candle light	27	2 W	13,5	0,027
Hall	E27 LED Filament Polaris	1	7,5 W	1	0,0075
Disabled toilet	E27 LED Filament Polaris	1	7,5 W	3,5	0,02625
Nature shop	Luminaire	2	28 W	22	0,616
Workshop	Luminaire	2	14 W	5	0,070
Changing room	Fluorescent tube	3	36 W	58,5	2,106
Stables	E27 LED Filament Polaris	2	7,5 W	1	0,0075
	Fluorescent tube	3	35 W	1,5	0,0525
	Construction lamp halogen	1	150 W	0,5	0,075
Emergency exit	White LED	3	1,5 W	109,5	0,164

It is not valid enough to state that the lighting schedule is constant per month. It is more likely that there is a correlation between the hours of lightning and the hours of sunshine. For the determination of the lighting schedule throughout the year is made use of normal sunshine hours. Normal hours of sunlight indicate how long the sun shone throughout a day. The lighting schedule is based on the month of November (2016). As a result, the lightning schedule will be normalized on the month November for the whole year. The total electric power usage for lighting in November (2016) is 7,74 kWh per week, so roughly 30 kWh per month.

The hours of sunlight are measured at the nearest KNMI weather station of the location. This is the weather station Twenthe. The number of hours of sunlight in November is 74,70 (KMNI, 2016). In 2016, the total number of hours of sunshine per year is 1809.90 (KMNI, 2016). Figure 19 shows the expected behavior of the electricity usage for lighting per month based on the hours of sunlight. The predicted annual electricity usage for lighting is 245,85 kWh.

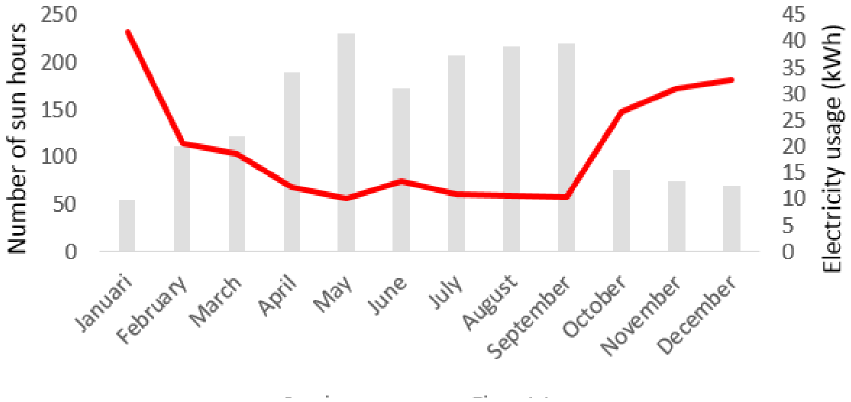

Figure 19: electricity usage for lighting per month based on the hours of sunlight, 2016

Appliances

The appliances that are present in Alldrik are measured by means of watt-hour meters during a week. This is a BASETech Cost Control 3000 and is simply placed between the mains socket and electrical appliance. The Cost Control 3000 has a power usage of 0,8 Watt and may not exceed maximum rated capacity of 3680 Watt.

The use of appliances depends on personal behavior. Due to the time restraints in this research is it difficult to map this specific behavior. Therefore, it is assumed that the use of appliances is weekly recurring behavior. Because of this assumption, the appliance usage per week will be considered as a constant. Most of the electrical appliances are located in the building of the meeting area. Table 25 shows an overview of the appliances that are in operation during a week. The appliances with a star (*) are bases on another method and can be found in Appendix D. The total electric power usage of the appliances in Alldrik is 26,17 kWh per week.

Table 25: electric power usage appliances Alldrik

Appliances	Start date/time	End date/time	Electricity usage per week
TV	11-15 at 12:00	22-11 at 12:00	1,11 kWh (42:20:15)
Coffee machine 1	11-15 at 12:00	22-11 at 12:00	1,48 kWh (01:51:42)
Coffee machine 2	11-15 at 12:00	22-11 at 12:00	0,56 kWh (00:37:07)
Water boiler	11-15 at 12:00	22-11 at 12:00	2,61 kWh (01:25:26)
Stereo	11-22 at 12:00	29-11 at 12:00	0,84 kWh (17:14:12)
Extractor fan kitchen*	N.A.N.	N.A.N.	0,456 kWh
Dishwasher	11-22 at 12:10	11-29 at 12:10	6,03 kWh (08:43:18)
Microwave*	N.A.N.	N.A.N.	0,11 kWh
Induction cooker*	N.A.N.	N.A.N.	7,236 kWh
Refrigerator	11-22 13:30	11-29 at 13:30	1,84 kWh (38:24:27)
Furnace	11-22 13:30	11-29 at 13:30	0,34 kWh (01:28:00)
Ventilation toilet*	N.A.N.	N.A.N.	0,084 kWh
Boiler*	N.A.N.	N.A.N.	0,34 kWh
Refrigerator (nature shop)	11-22 at 13:00	11-29 at 13:00	0,00 kWh (00:01:23)
Vacuum cleaner*	N.A.N.	N.A.N.	0,49 kWh

During the opening hours of Alldrik, there are appliances active in the dwelling that affect the electricity usage. The electricity usage of these appliances should be corrected to the openings hours of Alldrik in order to make a complete overview. Table 26 shows the electricity usage of the appliances in the dwelling during the opening hours op Alldrik. The appliances with a star (*) are based on another method that can be found in Appendix D.

Table 26: appliances of the dwelling that are in operation during the opening hours of Alldrik

Appliances	Start date/time	End date/time	Electricity usage per week	Electricity usage opening hours Alldrik
Refrigerator with freezer	11-22 at 13:00	11-19 at 13:00	2,66 kWh (45:05:11)	0,58 kWh
Built-in refrigerator*	N.A.N.	N.A.N.	3,31 kWh	0,72 kWh
Built-in freezer*	N.A.N.	N.A.N.	6,17 kWh	1,34 kWh

Electricity balance

The total energy usage of electricity during the opening hours of Alldrik is 30 kWh per week (Table 23). The energy balance is clarified for 96,9% by the examined electricity consumers. Therefore, it can be concluded that this energy balance gives a decent overview of the electric power use during the opening hours of Alldrik.

$$E_{electricity} = E_{lighting} + E_{appliances} + E_{miscellaneous} = 7{,}74 + 26{,}17 + E_{miscellaneous} = 35\ kWh\ per\ week\ during\ the\ opening\ hours\ of\ the\ social\ care\ farm$$

4.1.2 WATER CONSUMPTION BREAKDOWN

The water consumption of the social care farm is also measured in the period between Thursday, November 17th at 09:00 am and Thursday, November 24th. Analyzing these measurements, the total water consumption of Alldrik can be determined for one operational week. The water pipes for the social care farm are connected to the existing water system of the dwelling. The water pipes related to the meeting area are as follows: there is a cold water pipe to the kitchen (capped sink), disabled toilet (toilet + wash basin) and attic (boiler). Domestic hot water is provided by a combi boiler and passes hot water to the kitchen (capped sink). Furthermore, there are cold water pipes to the shed (outside tab) and the nature store (capped sink). The water consumption of Alldrik can be divided into four different categories: toilet visits, potable water, cooking water and water for the animals. The water balance for water consumption is as follows:

$$W_{water;total} = W_{toilet} + W_{drinking} + W_{cooking} + W_{animals} + W_{miscellaneous}$$

Water consumption disabled toilet (toilet and wash basin)

The water consumption from the wash basin and toilet depends on the user behavior and the flow rate of the facilities. To obtain an indication of the water consumption from the disabled toilet, the number of toilet visits, the average time of washing hands and the flow rate of the toilet/wash basin should be determined.

The utilization of the toilet with wash basin is based upon the number of present people and tested indicators. In this research, only the toilet visits to urinate are taken into consideration. A human urinates on average 3-7 times per day (LabDx holding B.V., 2016). Several assumptions have to be done in order to convert this average to actual toilet visits. It is assumed that a person sleeps between 23:00-07:00 and goes directly to the bathroom before and after this period. After this correction, There remain 16 hours for five toilet visits during the day. It is assumed that all these restroom visits happen in the opening hours of Alldrik. This equates to 0,3125 toilet visits per person per hour. These assumptions are made without taking into account the age and condition of the involved persons. Table 27 illustrate the restroom visits based on the average number of present people during the week in Alldrik.

Table 27: average restroom visits during the week

		Average number of attendees	Length of stay Alldrik	number of restroom visits
Thursday	17-11	12	7,5 hours	26,25 (27)
Friday	18-11	8	7,5 hours	18,75 (19)
Saturday	19-11	10	6,5 hours	20,31 (21)
Tuesday	22-11	10	7,5 hours	23,44 (24)
Wednesday	23-11	6	7,5 hours	14,06 (15)

The flow rates of the wash basin and the toilet are determined by means of measurements. Table 28 shows that the average flow rate of the wash basin is 5,9 liter per minute. According to Carl Borchgrevink (Pérez, 2013), people should take fifteen to twenty seconds to effectively wash their hands with soap and water for killing the germs. For the calculation in this research, the lower boundary of fifteen seconds is used as handwashing time. Therefore, 151,93 liter of handwashing water is used in one week during the openings hours of the social care farm.

Table 28: average flow rate of the wash basin

	Quantity	Time	Flow rate
Measurement 1	0,5 liter	5,5 seconds	5,46 l/min
Measurement 2	0,5 liter	4,7 seconds	6,38 l/min
Measurement 3	0,5 liter	5,3 seconds	5,66 l/min
Measurement 4	0,5 liter	5,1 seconds	5,88 l/min
Measurement 5	0,5 liter	4,9 seconds	6,12 l/min

The toilet in the meeting area is a wall closet without disposal point. In order to determine the volume of the flushing water, the water difference before and after the flush is observed. This difference is made visible by the water meter in the fuse box. Table 29 shows that the average volume of flush water is equal to 7±1 liter a time. Resulting in a total of 721 liters of flushing water in one week during the opening hours of the social care farm.

Table 29: volume of flushing water toilet

	Meter before	Meter after	Volume
Measurement 1	1724,678 m^3	1724,685 m^3	7 liter
Measurement 2	1724,747 m^3	1724,755 m^3	8 liter
Measurement 3	1725,432 m^3	1725,438 m^3	6 liter

Potable water

Throughout the day, a large amount of coffee/tea/water/lemonade is consumed during the opening hours of Alldrik. An adult requires on average 1,5 to 2 liter of moisture in the form of beverages a day (Voedingscentrum, 2016). Since Alldrik does not include an evening schedule, it is assumed that a present person drinks 1,5 liter at Alldrik. The quantity of potable water is based on the number of present people multiplied by 1,5 liter. The total quantity of consumed potable water is 69 liter in one week during the opening hours of the social care farm.

Cooking water

During the opening hours of Alldrik is cooked for a select group at the meeting area in the afternoon. The amount of water that is required for cooking is based on the number of those who eat and averages from WMB water. The average quantity of water consumption for food preparation is 1,4 liter per person (WMD, 2013). In Table 30 is shown how many ate dinner during the week. The total quantity water used for dinner in one week is 21 liter during the opening hours of the social care farm.

Table 30: water consumption for cooking during a week

	Number of people who ate dinner	Water consumption for cooking
Thursday 17-11	5	7 liter
Friday 18-11	3	4,2 liter
Saturday 19-11	0	0 liter
Tuesday 22-11	4	5,6 liter
Wednesday 23-11	3	4,2 liter

Dishwasher

The Amica EGSP dishwasher in the meeting area uses 9-liter water per default program. The dishwasher is in the measurement week 8 hours and 43 minutes in operation (Table 25). To finalize the default program, a time period of 104 minutes is needed (OTTO, 2006). The total amount water consumed by the dishwasher is 5 programs x 9 liters = 45 liter per week during the opening hours of the social care farm.

Water consumption by the horses

The social care farm Alldrik owns five Friesian horses. The horses consume, according to the owner (Henk van der Giesen red.), on average 30 liters per horse per day through a self-drinker. During a week, the horses consume together 750 liters of potable water during the opening hours of Alldrik.

On Saturdays, the five horses are cleaned with a garden hose. The horses are washed by the clients. Therefore, the water consumption per wash varies. On Saturday, November 19th is the amount of consumed water per wash measured. In order to determine the total quantity of wash water, the average volume of the five horses is used as a general figure. The average quantity wash water is 61,6 liter per horse (Table 31). Therefore, the total quantity is 308-liter wash water per week during the opening hours of the social care farm.

Table 31: water consumption by washing the horses

Mensuration	Meter before	Meter after	Quantity
Horse 1	1725,592 m^3	1725,627 m^3	35 liter
Horse 2	1725,631 m^3	1725,683 m^3	52 liter
Horse 3	1725,695 m^3	1725,805 m^3	110 liter
Horse 4	1725,812 m^3	1725,855 m^3	43 liter
Horse 5	1725,873 m^3	1725,941 m^3	68 liter

Water balance

The total amount of water consumed during the opening hours of Alldrik is 2,096 m^3 (Table 23). The water balance is clarified for 98,6% by the examined water consumers. Therefore, it can be concluded that this water balance gives a sufficient overview of the water consumption during the opening hours of Alldrik.

$$W_{water;total} = W_{toilet} + W_{drinking} + W_{cooking} + W_{animals} + W_{miscellaneous} = 0{,}873 + 0{,}069 + 0{,}066 + 1{,}058 + W_{miscellaneous} = 2{,}096\ m^3\ per\ week\ during\ the\ opening\ hours\ of\ the\ social\ care\ farm$$

4.1.3 NATURAL GAS USAGE BREAKDOWN

The gas pipelines are connected to the existing gas system of the dwelling. There is a gas pipeline toward the attic of the meeting area (boiler) and the nature store (gas stove). The gas stove in the nature store is out of service, The food should be preserved in a cold environment, and the exterior door is always open for customers. The natural gas usage of Alldrik is divided in domestic hot water and heating of the meeting area. The energy balance for natural gas is as follows:

$$E_{natural\ gas} = E_{domestic\ hot\ water} + E_{space\ heating} + E_{miscellaneous}$$

Domestic hot water

The single activity that uses domestic hot water during the opening hours of Alldrik is cooking (assumed that hands are washed with cold water). During the measurement week, 21 liters of water is consumed by the activity ‘cooking’ (see section water consumption: cooking water). The water is heated from 16 °C to 40 °C using an HR-107 boiler. The calculation for the energy demand is performed by using information from the BINAS (Verkerk et al, 2004). In this calculation, the energy demand for heating 21L water 24°K by using natural gas is determined. The formula to calculate this demand is as follows:

$$\text{The needed amount of energy (Q)} = \text{density (m) x specific heat (c) x change in temperature } (\Delta \text{T})$$

Specific heat water (293-373 K) = $4{,}18 \cdot 10^{3}\ J\ kg^{-1}\ K^{-1}$

Water density (293 K) = $0{,}998 \cdot 10^{3}\ kg\ m^{-3}$

Quantity of water = 21 liter = $0{,}021\ m^{3}$

Change of temperature = 24 K

$Q = (0{,}998 \cdot 10^{3} \times 0{,}021) \times 4{,}18 \cdot 10^{3} \times 24 = \underline{2{,}10 \cdot 10^{6}\ J}$

$Q_{needed} = 2{,}10 \cdot 10^{6}\ J$

$1\ m^{3}$ *natural gas =* $35{,}1 \cdot 10^{6}\ J$ *(high calorific value)*

Natural gas needed = $2{,}10 \cdot 10^{6} / 35{,}1 \cdot 10^{6} = \underline{0{,}06\ m^{3}}$

Considering the efficiency of the heat generation of Alldrik, a HR-107 boiler, a total of $2{,}10 \cdot 10^{6}$ J needs to be generated from natural gas. The HR-107 boiler has an efficiency of 85% for domestic hot water (see Appendix G). When using the efficiency of heat generation of Alldrik, this corresponds to 0,08 m^{3} of natural gas per week for heating domestic hot water.

The natural gas usage for domestic hot water is just 0,4% of the total natural gas usage during the opening hours of Alldrik. Therefore, it is assumed that the gas usage for domestic hot water can be neglected. In this research, space heating will be considered as the only consumer of natural gas.

Space heating

The determination of the natural gas usage is more complicated than determining the use of electricity and water. During the opening hours of Alldrik, both the heating systems (dwelling and meeting area) are in operation. The natural gas breakdown of the dwelling is determined by known figures because of the privacy of the residents and the lack of adequate measurements outside the opening hours of Alldrik. These figures should provide insight into the distribution of natural gas between the dwelling and the meeting area.

Calculation nature gas breakdown

During the opening hours of Alldrik, a total amount of 21,123 m^{3} natural gas is used (Table 23). By the neglect of the nature gas use for DHW (Figure 10), the total amount of natural gas is used for space heating in the meeting area and dwelling. Outside the opening hours of Alldrik, when the heating system in the meeting area is in night mode, a total amount of 45,854 m^{3} (Table 23) of natural gas is used. By extracting the natural gas needed for DHW and cooking, The total amount of natural gas used for heating outside the openings hours of Alldrik is 36,624 m^{3} per week.

When Alldrik is closed (Sunday and Monday) is the average natural gas usage 8,527 m^{2} per day (Appendix C) and on the other days is the natural gas usage 9,98 m^{3} per day, a difference of 1,458 m^{3}. This discrepancy can be explained by the fact that the heating system in the meeting area is operational on working days. Alldrik is open 36,5 hours per week, the day mode of the heating system in the meeting are uses $\frac{5 \times 1{,}458}{36{,}5}$ = 0,1997 m^{3} more natural gas than the night mode.

The average natural gas usage during the openings hours of Alldrik is $\frac{21{,}123}{36{,}5}$ = 0,58 m^3 per hour. When the heating system in the meeting area is in night mode, the natural gas usage is 0,58 – 0,1997 = 0,38 m^2 per hour. The heating system in the dwelling is at night mode between 23:00 o'clock and 08:00 o'clock. Alldrik is closed 131,5 hours a week, 63 hours in day mode and 68,5 hours in night mode. The total natural gas usage outside the opening hours of Alldrik is 0,38 x 63 = 23,94 m^3. When both heating systems (dwelling and meeting area) are operating in night mode, the natural gas usage per hour is $\frac{36{,}624-23{,}94}{68{,}5}$ = 0,185 m^3. The difference in natural gas usage for night and day mode of the heating system in the dwelling is 0,38 – 0,185 = 0,195 m^3. Therefore, the ratio of the natural gas usage between the meeting area and dwelling is 0,1997/0,1950 = 50,6%/49,4%.

Natural gas balance

It is assumed that the total natural gas usage is consumed by space heating. Therefore, the energy balance should be redrafted as follows:

$$E_{natural\ gas} = E_{space\ heating}$$

However, the natural gas usage of the heating system in the dwelling should be taken into account to determine the natural gas usage of Alldrik during the opening hours. It has been calculated that the natural gas usage ratio between the meeting area and the dwelling equals 50,6%/49,4%. Therefore, a new energy balance can be formulated:

$$E_{natural\ gas} = E_{domestic\ hot\ water} + E_{space\ heating} + E_{miscellaneous} = E_{space\ heating} = E_{space\ heating;meeting\ area} + E_{space\ heating;dwelling} = 1069 + 10{,}43 = 21{,}123\ m^3\ per\ week\ during\ the\ opning\ hours\ of\ the\ social\ care\ farm$$

4.1.4 ANALYSIS TOTAL ENERGY BREAKDOWN

The breakdown of the energy use is based on measurements on site. In Section 4.1, the breakdown of the energy use is determined for natural gas and electricity. With this information, a total energy breakdown for Alldrik can be made. During the measurement in one week is determined that 29% of the total annual electricity usage and 32% of the total annual natural gas usage is used during the opening hours of Alldrik. This is according to the measurements on site 7.088 MJ electricity and 27.957 MJ natural gas. The annual energy breakdown of Alldrik is made visible in Figure 20. This breakdown shows that the main energy is consumed by natural gas for space heating for both buildings.

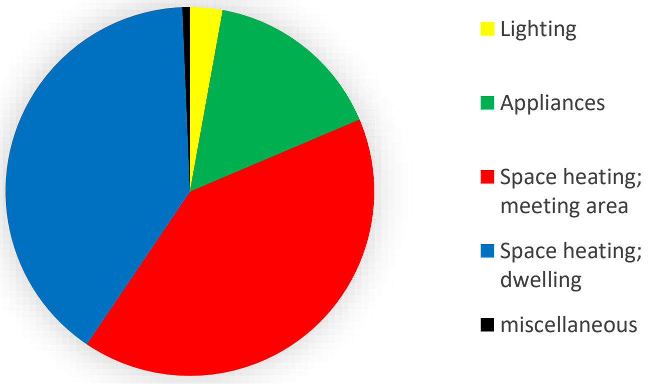

Figure 20: annual break down Alldrik during opening hours

4.2 MEASURES FOR ENERGY PERFORMANCE IMPROVEMENT

Earlier, it was made clear that energy usage in the buildings sector makes significant contributions to global warming and pollutant emissions. Therefore, it is important to improve the energy performance of buildings. In this section, insight will be given into the possibilities to reduce the net annual energy demand of social care farms. The most important measures required to reduce the energy dependency and greenhouse gas emission in the European Union are the use of energy from renewable sources and the reduction of the general energy usage (Official Journal of the European Union, 2010). In many European countries, policymakers are embracing the new concept of 'net-zero-energy buildings' (nZEB) as a method to meet the energy reduction targets (Crawley, Pless, & Torcellini, 2009). A net zero-energy building is a building which energy demand is equal to its energy usage in a particular period of time (Torcellini, Pless, Deru, & Crawley, 2006).

In the buildings sector, the only way the generate energy is by using renewable energy sources. The energy usage in buildings includes cooling, heating, lighting, ventilation and appliances (Mohamed , Cao, & Hasan, 2014). In the study of Mohamed et al. (2014) is made an energy balance of a nZEB. The generated energy is the 'export energy' and the used energy is the 'import energy'. The energy balance is achieved if the net primary energy is less or equal than zero, shown as:

$$Net\ primary\ energy = \sum_{i}^{n} PE_{import,i} - \sum_{j}^{m} PE_{export,j} \leq 0$$

Based on this equation, two common strategies are used to achieve this net primary energy usage in buildings (Favoino, Overend, & Jin, 2015): minimize the total energy demand of the building and supply the energy demand that remains by means of on-site renewable energy sources. This is consistent with the targets of the European Union and will be the basis in the process of becoming more sustainable in this research.

In Chapter 2, the benchmarking process for the energy performance is described between social care farms. First, it necessary to develop a database of the information concerning the energy performance of a significant number of social care farms. This 'energy' information should be categorized and normalized. As a result, the relevant information to determine the EPI for the actual social care farm. To improve the individual social care farms, a comparative analysis of the social care farm against the samples held in the database gives a quantification of the quality of the social care farm in terms of energy usage. With this comparison, the potential areas for improvement are made visible for the individual social care farm. Figure 21 shows the four stages for social care farms to become more sustainable.

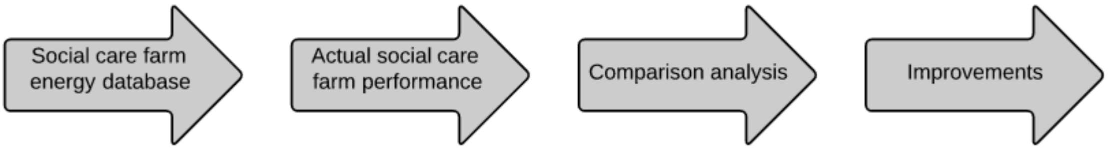

Figure 21: four stages to achieve a better energy performance for social care farms

In the Netherlands, there is already an extensive knowledge base about making buildings energy-neutral in a sustainable manner. However, this knowledge about the more innovative techniques is still fragmented. In this Research, the aim is to achieve an EPC=0 to minimalize the CO_2 emissions. Due to the size of an average social care farm, the innovative techniques are examined at dwelling level. Within the

Innovation Agenda Energy in the Built Environment of the TKI EnerGO, the following program lines are determined to improve innovation in the field of sustainability (TKI EnerGO, 2013):

- Sustainable conversion
- Sustainable storage
- Energy regulation and control
- Multifunctional building elements
- Energy generation, distribution, and storage at site level

The Rijksdienst voor Ondernemend Nederland (RVO) has subsequently translated this program lines to ten main techniques to achieve an EPC=0 situation (RVO, 2014). These formulated techniques can be found in Table 32. By doing a comparison analysis between social care farms, the potential technique could be revealed for a specific social care farm.

Table 32: different kind of techniques to make a building more sustainable

Techniques		
Heat pumps	Compact storage	Glass and transparent facade parts
Natural gas applications	Energy generation	Climate active construction elements
Ventilation	Thermal insulation	
Distribution systems	Limiting air permeability	

The techniques formulated by the RVO are related to the Trias Energetica that refers to three categories of measures, which can improve the sustainability of the energy usage of a dwelling (Entrop & Brouwers, 2009): (step 1) take measures which reduce the building's energy need, (step 2) use as many renewable sources to keep the energy demand as sustainable as possible and (step 3) use the necessary fossil sources as effectively as possible. To control and limit the energy usage effectively, the chosen technique should cover minimal one of the three step of the Trias Energetica. Which technique is preferable depends on the energy performance of the specific social care farm. Another reason to use a particular technique is the preference of the owner. For example, the wish to use only electricity or increase the efficiency of the building. In the continuation of this research, we distinguish applied system techniques and characteristic architectural techniques to reduce the EPC of a building. The choice of a particular technique to reduce the EPC strongly depends on the possibilities and willingness of the social care farm. This research will outline a couple of the techniques and investigate the consequences with respect to the EPC based on social care farm Alldrik

4.3 TECHNIQUES CASE STUDY

To make the right choice for a specific technique, the current situation of the building should be carefully examined. An applied technique has the best result if it is a big improvement compared to the previous situation. An inventory of the current state of a building can provide the first filtering in the technique decision.

Alldrik has already taken huge steps in improving the sustainability of the social care farm. The dwelling has undergone a complete renovation, involving cavity wall insulation and HR ++ glazing. Furthermore, the meeting area was recently built in a sustainable way (insulation, HR++ etc.). As a result, the improvement of the thermal envelope will have a minimal effect in comparison with the costs that are incurred. Also, Alldrik replaced a large part of the lighting by renewable LEDs, which remains a minimal profit. In the case study, the maximum profit to reduce the EPC is by optimizing the applied systems of the building. The techniques chosen for the case should cover step 2 and 3 of the Trias Energetica: sustainable energy sources and efficient use of fossil fuels.

4.3.1 PV-PANELS (STEP 2)

During the period of this research, an important step is made concerning the reduction of the EPC. On October 27, 12 PV-panels are placed on the roof of the work shed, and 24 PV-panels are placed on the roof of the meeting area. These are DMEGC mono all-black 60-cells PV-panels (dim. 1650x992x40 mm) with a peak power of 275 Wp. The total cost (materials, mounting and installation) excluding VAT is € 9.557,- and the PV-panels are located as shown in Figure 22. Figure 22 shows that the shadow of the roof of work shed affect the efficiency of the PV-panels on the roof of the meeting area.

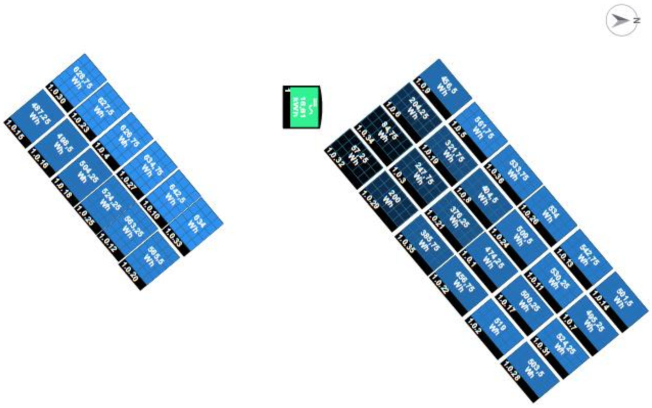

Figure 22: positioning PV-panels Alldrik

Annual electricity generation

To determine the effect of the PV-panels on the EPC, the annual energy generation of the PV-panels is examined. As is known, the yield of a PV-panel depends on the amount of sunlight that it captures. The yield of a PV-panel is expressed in Wp, which stands for Watt peak. Wp represents the yield in an ideal circumstance. Therefore, the given 275 Wp of the PV-Panel does not mean that the yield of the panel is actually 275 Wp. However, the actual yield of a PV-panel can be easily calculated by using the conversion factor for the Netherlands (TKI EnerGO, 2013). For the determination of the conversion factor, use was made of a yield scan by zonnepanelen.net. The situation of Alldrik is analyzed with sophisticated software at a distance. In addition, the climate data from Markelo have been used. In the situation of Alldrik are solar radiation, slope, and orientation to the south used as calculation factors. The conversion factor of Markelo is 0,83 and the reduction factor for Alldrik is calculated at 0,96.

The maximum annual theoretical electricity generation by the PV-panels of Alldrik is 7888 kWh (=275 x 36 x 0,83 x 0,96). How this electricity generation is divided over the year can be determined by full hours of sunlight per month. A full hour of sun corresponds to the amount of energy of the sun that is absorbed by a flat surface in one hour; this is about 1 kWh/m^2. To calibrate the number of full sunlight with the electricity generation per month, two known months are used for the whole year. The producer of the PV-panels had added an online program that allows the owner to follow the electricity generation. In the period of the research, the electricity generation of November (261,377 kWh) and December (175,228) are known.

Figure 23 shows the electricity generation per month in 2016. The red line is the electricity generation based on the full hours of sunlight and the two sample months. The green line is the electricity generation per month corrected by the maximum annual electricity generation based on the Watt peak of the PV-panels.

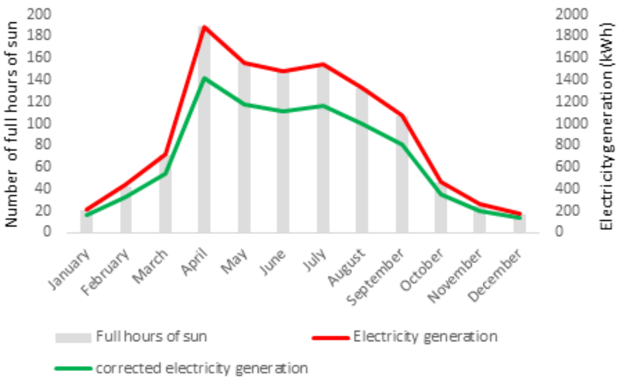

Figure 23: electricity generation PV-panels per month, 2016

Electricity surplus

In a situation of electricity surplus from the PV-panels, there can be made use of the offsetting arrangement. the offsetting arrangement dates from 2004 and can be found in the Dutch Electricity Act (Art. 31c). Offset means that the user's self-generated electricity is directly redelivered to the utility company and therefore can be subtracted at the moment that the PV-panels does not provide enough solar energy. This offset occurs at the same cost as the purchased electricity, so the delivery price of the producer, including energy tax, renewable energy storage, and sales tax.

Minister Kamp has, at the request of Holland Solar, made an explicit statement in the Dutch parliament on the future of the offsetting in the Netherlands. The offset will remain legally entitled to at least 2020 and thereafter shall follow a decent transitional arrangement. A new system will be developed from 2017 and should start from 2020. The premise is that PV-panels remain financially attractive, even after 2020 (Holland Solar, 2016).

Tax deductions

To ensure that companies can purchase their solar systems and simultaneously earn back the investment quickly, several options for tax deductions are available. In 2017, the diverse arrangements for SMEs (small and medium enterprises) are the EIA and KIA (Subsidie-zonnepanelen, 2017).

The EIA (Energie-ivesteringsaftrek) is a tax deduction. With this deduction, the government tries to encourage investment in energy-efficient equipment or renewable energy such as PV-panels. This arrangement is primarily intended for entrepreneurs in the Netherlands who pay income tax or company tax. Through the EIA, entrepreneurs who invest in solar power systems can receive additional deductions from taxable profit. The solar investment should be over € 2200, - (RVO, 2017). Application of the EIA provides 11% deduction of the total investment on average (RVO, 2017).

In addition to the EIA, the investment of PV-panels may affect eligibility for the KIA (Kleinschalig investeringsafstrek). An important condition is that the investment must be an amount between € 2.200 and € 300.000 in PV-panels for the company in a financial year (ProfiNRG, 2017). The KIA depends on the amount of money invested in the PV-panels. Table 33 shows the KIA in correlation with the invested amount of money.

Table 33: Kleinschaligheidsinvesteringsaftrek (KIA)

Low boundary	High boundary	KIA
€ 0,-	€ 2.200,-	N.A.
€ 2.200,-	€ 54.324,-	28% of the investment
€ 54.324,-	€ 100.600,-	€ 15.211,-
€ 100.000,-	€ 301.800,-	€ 15.211,- reduced by 7.56% of the portion of the investment that exceeds the € 100.600,-

4.3.2 HEAT PUMP (STEP 2 AND 3)

Both the meeting area and dwelling possess a HR-107 boiler, therefore is the hybrid heat pump an interesting technique to reduce the energy usage in a short period. A hybrid heat pump is a combination between an electric (air/water) heat pump and a central heating system on natural gas. A hybrid heat pump is well applicable to existing dwelling because of the minimal structural adjustments. The air/water heat pump has an outer unit which only uses the ambient air as a source. The generated heat is only used for space heating; the HR-boiler covers the domestic hot water.

In this research, the Techneco Elga heat pump is chosen. The Techneco Elga is an electric air-water hybrid heat pump with an indoor and outdoor unit. The small indoor unit is placed next to a high-efficiency boiler or at the connection of the district heating. The heat pump can deliver 5 kW of heat and can be installed in combination with every boiler. The Techneco Elga heat pump costs € 4.435,- including VAT and installation (price: www.cvtotaal.nl).

Impact heat pump on the premises of Alldrik

The impact of the pump on the two heated building of Alldrik is determined with calculation program from the manufacturer of the selected heat pump and computer program Vabi Elements. With the savings test of the manufacturer (Techneco, 2017), an estimation of the influence of the heat pump can be made. Through the use of the Elga in the dwelling, the annual natural gas usage is reduced by 880 m^3 (= 30.888 MJ) and the annual electricity usage will increase by 1340 kWh (= 1742 MJ). When the Elga is installed in the meeting area, the annual natural gas usage is reduced by 290 m^3 (= 10.179 MJ) and the annual electricity usage will increase by 500 kWh (= 650 MJ). As a result, the amount of energy needed for space heating will reduce by ± 50% for the dwelling and ± 33% for the meeting area.

The calculation program of the manufacturer does not contain the geometry of the building and cannot be seen as independent. Therefore, a simulation of the both buildings including heat pumps is performed in Vabi Elements to determine the reduction of the energy demand for space heating. The results of the Vabi Elements calculation concerning the heat pump can be found in Table 34. Through the use of a heat pump in the dwelling, the annual natural gas usage will reduce by 1509 m^3, but the annual electricity usage increase by 30.921 kWh. This is much more than the estimated 1340 kWh by the program of the manufacturer. When a heat pump is installed in the meeting area, the annual natural gas usage is reduced by 993 m^3 and the annual electricity usage is increased by 8639 kWh. Again, this is much more than the assessed value. The total reduction of the annual energy demand for space heating according to Vabi Elements is ± 15% for the dwelling and ± 11% for the meeting area.

Table 34: results comparison buildings Alldrik with and without the use of a heat pump in Vabi Elements

Dwelling	Natural gas (standard)	Electricity (standard)	Natural gas (heat pump)	Electricity (heat pump)
Space heating	82.927 MJ	0	29.960 MJ	40.198 MJ
Hot domestic water	24.846 MJ	0	24.846 MJ	0
Lighting	0	10.984 MJ	0	10.984 MJ
Total	107.773 MJ	10.984 MJ	54.806 MJ	51.182 MJ
Meeting area	**Natural gas (standard)**	**Electricity (standard)**	**Natural gas (heat pump)**	**Electricity (heat pump)**
Space heating	35.917 MJ	0	1.057 MJ	31.100 MJ
Hot domestic water	2.407 MJ	0	2.407 MJ	0
Lighting	0	9.012 MJ	0	9.012 MJ
Total	38.324 MJ	9.012 MJ	3.464 MJ	30.112 MJ

Investment Subsidy Durable Energy (ISDE)

ISDE is a subsidy from the Ministry of Economic Affairs. RVO is responsible for implementation in the Netherlands. With the application of the ISDE, an allowance for the purchase of inter alia heat pumps can be received. The arrangement is for both individuals and business users.

In 2017, the arrangement of the ISDE is changed (RVO, 2017). The boundaries of the power for the air-water heat pumps have been changed, as well as related amounts of subsidy. The amounts of subsidy in correlation with the power of the air-water heat pump can be found in Table 35.

Table 35: Investment Subsidy Durable Energy (ISDE)

Low boundary	High boundary	ISDE
0 kW	3,5 kW	€ 1.000,-
3,5 kW	10 kW	€ 2.000,-
10 kW	>10 kW	€ 2.000,- increased by € 100,- for each kW of thermal capacity greater than 10 kW

4.3.3 SOLAR BOILER (STEP 2)

A solar boiler uses sunlight to heat hot water. This heated water can be used as domestic hot water and therefore suitable for cooking or showering. With an additional heat exchanger can the solar boiler function as a solar heating system for both space heating and domestic hot water. A solar heater consists of the following components: solar collector(s), storage vessel and post heater. In this research, the HRS200D/4,8 solar boiler is chosen to examine the influence on the energy demand. The solar boiler has a 200-liter double helix storage vessel and standard three solar collectors with each a surface of 1,6 m^2 (similar as the PV-panel). The solar boiler with three solar collectors will cost around €4425,- inclusive VAT increased by €564,- per addition solar collector. Both the technique for using the solar boiler for domestic hot water and the technique for using the solar boiler for space heating and domestic hot water will be examined.

Hot domestic water

The influence of the solar boiler on the energy demand of domestic hot water is determined with computer program Vabi Elements. The effect of the solar water heater is determined by varying the number of solar collectors; the collectors are placed with an angle of inclination of 45°. The results of the Vabi Elements calculation can be found in Table 36. The calculations show a natural gas reduction for domestic hot water in the dwelling between 22-60% and a reduction for domestic in the meeting area between 40-100%.

Table 36: natural gas reduction domestic hot water in correlation with the number of collectors

Dwelling	Natural gas (standard)	Natural gas (1 collector)	Natural gas (2 collectors)	Natural gas (3 collectors)	Natural gas (4 collectors)	Natural gas (5 collectors)
Hot domestic water	24.846 MJ	19.249 MJ	14.700 MJ	11.227 MJ	10.890 MJ	9.994 MJ
∆standard	0	-22,5%	-40,8%	-54,8%	-56,2%	-59,8%
Investment	0	€3.291,-	€3.861,-	€4.425,-	€4.989,-	€5.553,-
Meeting area	**Natural gas (standard)**	**Natural gas (1 collector)**	**Natural gas (2 collectors)**	**Natural gas (3 collectors)**	**Natural gas (4 collectors)**	**Natural gas (5 collectors)**
Hot domestic water	2.407 MJ	1.427 MJ	1.035 MJ	837 MJ	0 MJ	0 MJ
∆standard	0	-40,7%	-57,0%	-65,2%	-100%	-100%
Investment	0	€3.291,-	€3.861,-	€4.425,-	€4.989,-	€5.553,-

Solar heating system for heating and domestic hot water

This option cannot be included in the EPG calculation in Vabi Elements (Vabi Elements, 2014). Therefore an estimation of the energy reduction is made with the expected yield from the manufacturer.

The expected annual yield for the solar boiler HRS200D/4,8 (200-liter double helix Single Barrel / 3 collectors 1,6 m^2) lies between 530-680 m^3 natural gas (HRSolar, 2017). In this research, it is assumed that the solar heating system for heating and domestic hot water will behave similar to the solar heating system for just the domestic hot water, see Table 37.

Table 37: annual natural gas reduction in correlation with the number of collectors

Building	Natural gas (1 collector)	Natural gas (2 collectors)	Natural gas (3 collectors)	Natural gas (4 collectors)	Natural gas (5 collectors)
Dwelling	(373-478) m^3	(456-585) m^3	(530-680) m^3	(537-690) m^3	(556-715) m^3
Meeting area	(400-513) m^3	(487-624) m^3	(530-680) m^3	N.A.	N.A.

The investment costs of the solar heating system with three collectors is €4.890,- including VAT and exclusive installation. By letting different contractors make a bid, the prize may be driven down.

Subsidy purchase costs

The purchase of a solar boiler is also covered by ISDE. The subsidy for solar boilers is € 0,75 per kWh annual solar energy contribution with an area that is not exceeding 10 square meters. This solar energy contribution is described in the 'list of solar boiler devices' of the RVO (RVO, 2017). In this list of boiler devices, the HRsolar Hrs200D/4,8 (with a total collector surface of 4,8 m^3) has an annual energy contribution of 1321 kWh. Therefore, the subsidy for this device is €661,- in 2017. By adding more collector surface, this amount will increase.

4.3.4 MISCELLANEOUS TECHNIQUES

Heat recovery from shower water (step 3)

Thermal energy from water offers unprecedented possibilities. The total used hot water is largely centrally generated and distributed through the hot water pipe (85%) and partly (15%) through equipment bound use (washing machine, dishwasher, electric kettle) produced by electricity (RVO, 2014). In the case of the domestic appliances (hot water produced by electricity), the preparation of cold water to hot water and the discharge of hot waste water do not occur simultaneously. When heating cold water to hot water through natural gas, this process does take place at the same time. The water from the shower has a large share in the overall hot water usage. When using a heat exchanger, approximately 60 to 65% of the heat can be recovered from the shower water (milieu centraal, 2016). There are various options for heat recovery from shower water:

- shower pipe heat recovery. This is a vertical system suitable for a bathroom on a floor. Instead of a conventional discharge tube, a vertical double-walled copper heat exchanger is placed underneath the shower basin.
- Shower basin heat recovery (horizontal). If there are no vertical drain is possible, use can be made of a shower basin heat recovery. This consists of a special shower basin, in which a horizontal heat exchanger is built-in.

To make an indication of the costs and benefits of water recovery from the shower, there is made of the average figures (OfferteAdviseur, 2017). In other words, the more use of the shower, the more benefit from the heat recovery system. However, heat recovery systems have been developed for new constructions and large-scale renovation. Due to the high degree of difficulty to install only a heat exchanger, the installation costs may be higher. The average investment and savings can be found in Table 38.

Table 38: average investment and savings shower water heat recovery systems (OfferteAdviseur, 2017)

System	Price range system	Additional costs shower basin	Installation costs	Annual natural gas savings
Shower pipe (vertical)	€400-700,-	None	€200,-	105 m^3
Shower basin (horizontal)	€800-1.000,-	€300,-	€1.000,-	85 m^3

By using Vabi Elements, an approximation of the reduction of energy demand by applicate shower water heat recovery can be made. Keeping in mind that one of the three bathrooms is located on the ground floor. Therefore, only the horizontal shower basin system can be used. As a result, the Vabi Elements calculation gives an annual energy demand reduction of 3612 MJ (= 103 m^3) natural gas.

Small-scale wind energy (step 2)

Small wind turbines are turbines that are specially designed for application on or near buildings. This means that they function optimally under the wind regime in the built environment and can resist sudden wind gusts and turbulence. In addition, they are safe, quiet, and they form a visual and completely constructive with the objects nearby. The power of these turbines lies between 0,5 and 20 kW. the purchase of a wind turbine is a huge investment compared to other sustainable techniques. The cost of a turbine type as specified by the supplier lie between €5.700–17.838,- for the total investment including VAT and installation, this correspond to 3.300-9.100 €/kW (Cace & ter Horst, 2007).

TU Delft (2011) has made calculations regarding the possible specific yield of small wind turbines. As Result that, the specific yield lies between 150-400 kWh/m^2/year at an average wind speed of 5,5 m/s. For comparison, the yields of large turbines lie between 800-1200 kWh/m^2/ year. On the other hand, small turbines are still at the beginning of their learning curve. It is expected that the efficiency in the future will be significantly improved. Another argument is that there is not enough information about the effects of small wind turbines in the Netherlands. Therefore, the investment in small wind turbines is yet not a wise investment to make the social care farm more sustainable. However, wind energy has potential to become a profitable technique for improving the sustainability of (small) buildings.

5 DISCUSSIONS

Following this research, there are uncertainties to consider. A large component of this research is collecting the actual energy performance of a social care farm for a new benchmark. This actual energy performance is based on an entire year. Due to time limitation, the actual measurements have been supplemented with prognoses. This implies that no account is taken of vacations or absenteeism. In this research, every week of the year will appear the same corrected with only the hours of sun and degree days. This assumption should be taken into consideration because it affects the accuracy of the annual energy usage.

The breakdown of the electricity usage on site is based on measurements and information of the manufacturer. The manufacturer's specifications are based on fully exploiting the power of the device. Usually, the device does not need the full power or lost a percentage by aging. Therefore, the theoretical electricity usage may be higher than the actual electricity usage. This can have consequences for miscellaneous electricity consumers who use more than is expected.

The theoretical annual energy usage of the buildings is calculated with Vabi Elements. Vabi Elements does not include the electrical appliances and user behavior. As a result, the theoretical energy use can not directly compared to the actual energy use and the energy bills. Furthermore, the thermal envelope of the building should be implemented precisely by means of the construction specifications. If these specifications are not been available, basic ISSO values are used. These ISSO values are not equal to the actual conditions and affect the reliability of the Vabi calculations.

For the assumptions or figures on user behavior, an average person is taken into account. However, the situation involves a social care farm. In general, the clients will not behave like an average person. This means that the known figures from literature do not sufficiently cover the target group in this research. Thus, the behavior assumptions that are based on literature are not solid enough to make factual statements.

The eventual outcome of this research is a guideline to assess the energy performance of social care farms. The energy performance indicator calculated by the multiple regression model is based on a database with sufficient samples. This research used a case study to create one sample for this database by means of a detailed research on site. In order to validate the final guideline, there are multiple samples required. This means that the value of the newly developed energy label is only visible when more data is available. By the method described in this research, it will take a lot of time to collect sufficient data to evaluate this label.

6 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The adoption of sustainable techniques and measures in social care farms is a complex task facing three main critical issues: (1) definition of the energy performance, (2) energy information in the labeling process and (3) identification of potential energy efficiency measures.

(1) There in no definition of the energy performance. The development of a new energy performance calculation tool, the normalized EPI, can create a benchmark for social care farms based on an energy label. The normalized EPI is calculated with a multi regression model that fits the characteristics of a social care farm. With data set n, a normal distribution can be made to classify the social care farm energy performance related by assigning an energy label. The definition of the scale for the energy label is clear, where the 'A' classification expresses the best energy performance and the 'G' classification the worst energy performance. As a result, a comparison scenario of the energy performance of social care farms.

(2) The lack of energy information in the labeling process. Three different approaches are examined to determine the annual energy usage of social care farm Alldrik: the energy bills kept by the utility company, measurements on site and the theoretical use calculated by Vabi Elements. The annual energy usage is divided between the natural gas usage and electricity usage and can be found in Table 39. An important point to call into question is the lack of electronic appliances in the theoretical energy usage. Therefore, the theoretical energy usage has a large difference in energy demand compared to the other methods. This difference in energy demand could be explained by the calculation in Vabi Elements. Vabi Elements calculates the buildings as fully operational in a year, while the operational hours of the two buildings are in correlation with each other. The electricity demand difference of the measurements on site in 2016-2017 can be explained by the presence of the PV-panels since October 27, treated in Section 4.3.1. It is assumed that the measurements on the site follow the energy bill of 2015-2016 registered by the utility company. Therefore, the annual energy usage of the measurements on the site is considered as the most reliable. However, the theoretical annual energy usage could still be helpful by findings manners to reduce the EPC.

Table 39: annual energy usage determined in three manners

	Energy bill (2014-2015)	Energy bill (2015-2016)	Measurements (2016-2017)	Theoretical
$Q_{natural\ gas}$	100.666 MJ	90.663 MJ	87.366 MJ	149.977 MJ
$Q_{electricity}$	43.124 MJ	36.252 MJ	24.440 MJ	19.996 MJ
Q_{total}	143.790 MJ	126.915 MJ	111.806 MJ	169.973 MJ

(3) the identification of potential energy efficiency measures. In order to improve the EPC of a building, the annual energy demand should be reduced. Table 40 shows the costs per MJ for the selected techniques mentioned earlier. It is important to examine what kind of energy is reduced for calculation the actual costs. A megajoule of natural gas is cheaper than a megajoule of electricity. For the improvement of the EPC, the energy costs are not taken into consideration. From the information gathered in Chapter 4, it can be concluded that a huge reduction of the annual energy demand can be obtained by using a fitting technique. This fitting technique can be distracted from a tailor-made analysis of a specific social care farm based on the Trias Energetica.

Table 40: the reduction of the total energy demand in correlation with the price per technique

Technique	Building	Type	Costs total	VAT	Deduction	Source	Costs per MJ
Pv-panels	Dwelling/meeting area	36 PV-panels	€9.557,-	Exclusive	€3.272,-	Manufacturer	0,61 €/MJ excl.
Heat pump	Dwelling	Techneco Elga	€4.435,-	Inclusive	€2.000,-	Manufacturer	0,08 €/MJ incl.
Heat pump	Meeting area	Techneco Elga	€4.435,-	Inclusive	€2.000,-	Manufacturer	0,26 €/MJ incl.
Heat pump	Dwelling	Techneco Elga	€4.435,-	Inclusive	€2.000,-	Vabi Elements	0,19 €/MJ incl.
Heat pump	Meeting area	Techneco Elga	€4.435,-	Inclusive	€2.000,-	Vabi Elements	0,18 €/MJ incl.
Solar boiler DHW	Dwelling	3 solar collectors	€4.425,-	Inclusive	€661,-	Vabi Elements	0,27 €/MJ incl.
Solar boiler DHW	Meeting area	3 solar collectors	€4.425,-	Inclusive	€661,-	Vabi Elements	2,40 €/MJ incl.
Solar boiler DHW + heating	Dwelling/meeting area	3 solar collectors	€4.890,-	Inclusive	€661,-	Manufacturer	0,18-0,23 €/MJ incl.
Heat recovery from shower water	Dwelling	2 shower pipe (vertical)	€1000-1600	Inclusive	N.A.	Manufacturer	0,14-0,22 €/MJ incl.
Heat recovery from shower water	Dwelling	Shower basis (horizontal)	€2100-2300	Inclusive	N.A.	Manufacturer	0,70-0,77 €/MJ incl.

The new energy label can be a great tool for the assessment of the energy performance, both for new and existing social care farms, in standardized or actual conditions. The energy benchmark provides a comparative appraisal of the energy performance of a social care farm in a comparison scenario. The energy classification can clarify whether measures should be taken or not in terms of energy efficiency, with the overall aim of reducing the CO_2 emissions. The success of the new energy label will almost certainly depend on the number of social care farms in the dataset and the credibility achieved by actual energy savings and CO_2 reduction. Therefore, further studies should be performed to show the actual outcome of the new energy label for social care farms.

6.2 RECOMMENDATIONS

The main goal this research is to develop a new benchmark for social care farms to assess their energy performance. Therefore, the input for this new benchmark should be collected due to the lack of information of energy use of social care farms. This information could be collected in two different ways: sent a questionnaire including the requested information to all the social care farms in the Netherlands or do a study on site at the social care farms. Both methods have their pros and cons; the questionnaire ensures a multitude of information in a relatively short period of time, but the measurements on site guarantee more quality of the eventual results. In this research is chosen for the measurements on site to provide a more qualitative and scientific basis for the new benchmark. However, the calculated EPI is based on a multiple regression model. The multi regression model is more reliable when using a larger dataset. This larger dataset can be obtained easier by using a questionnaire. For further studies, I would recommend a qualitative questionnaire to create this dataset.

Furthermore, this research has made a start into investigating which components are needed to collect the suitable data for the energy label. In a case study, the annual energy usage and breakdown is examined. The annual figures are based on measurements in research period. However, measurements during the whole year are needed to obtain significantly better results which take into account monthly/weekly conditions. Therefore, I recommend that owners/employers of social care farms keep track of their energy usage. This will eventually result in a better accounting system that could be easily imported as input for the dataset.

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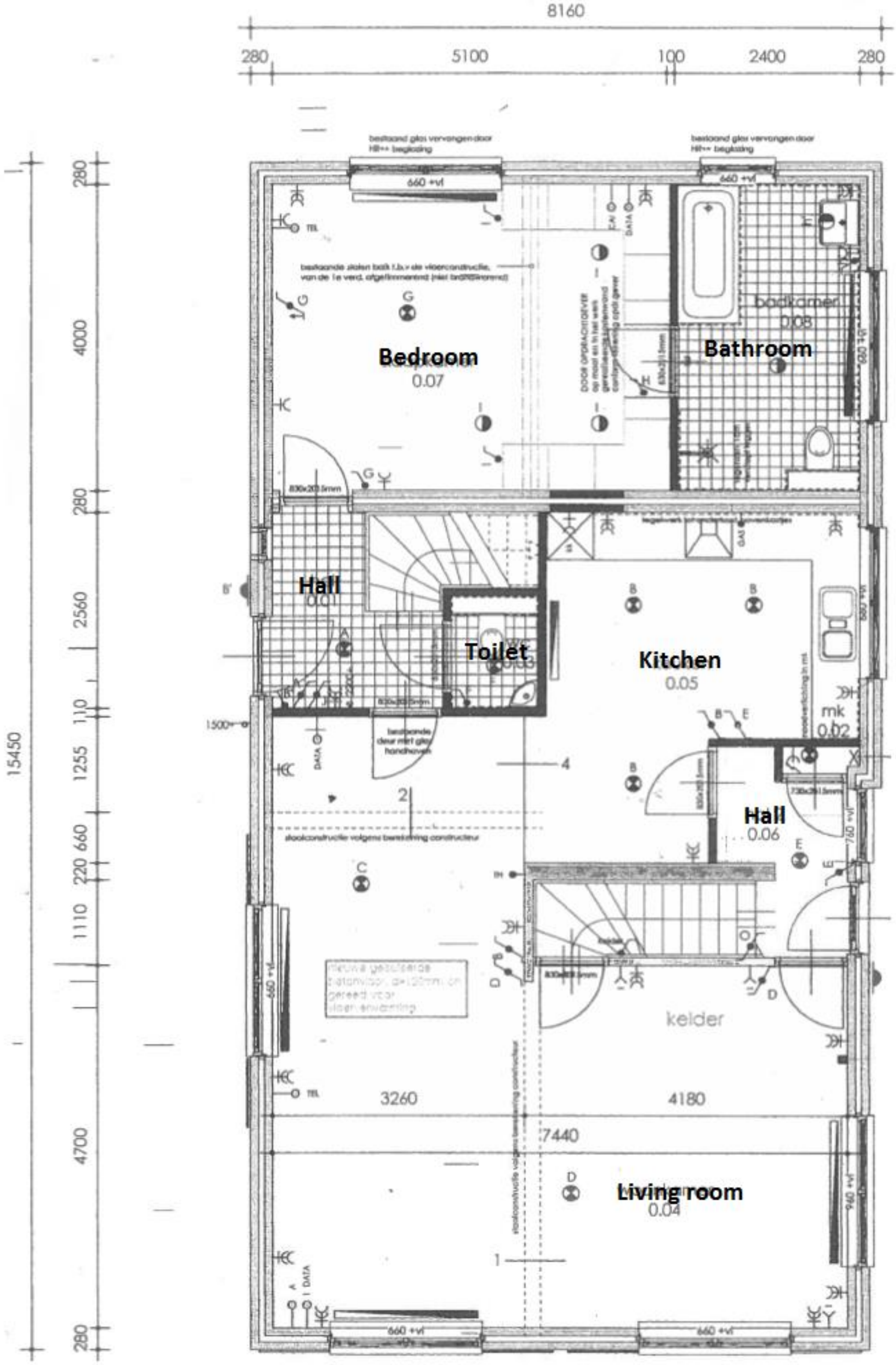
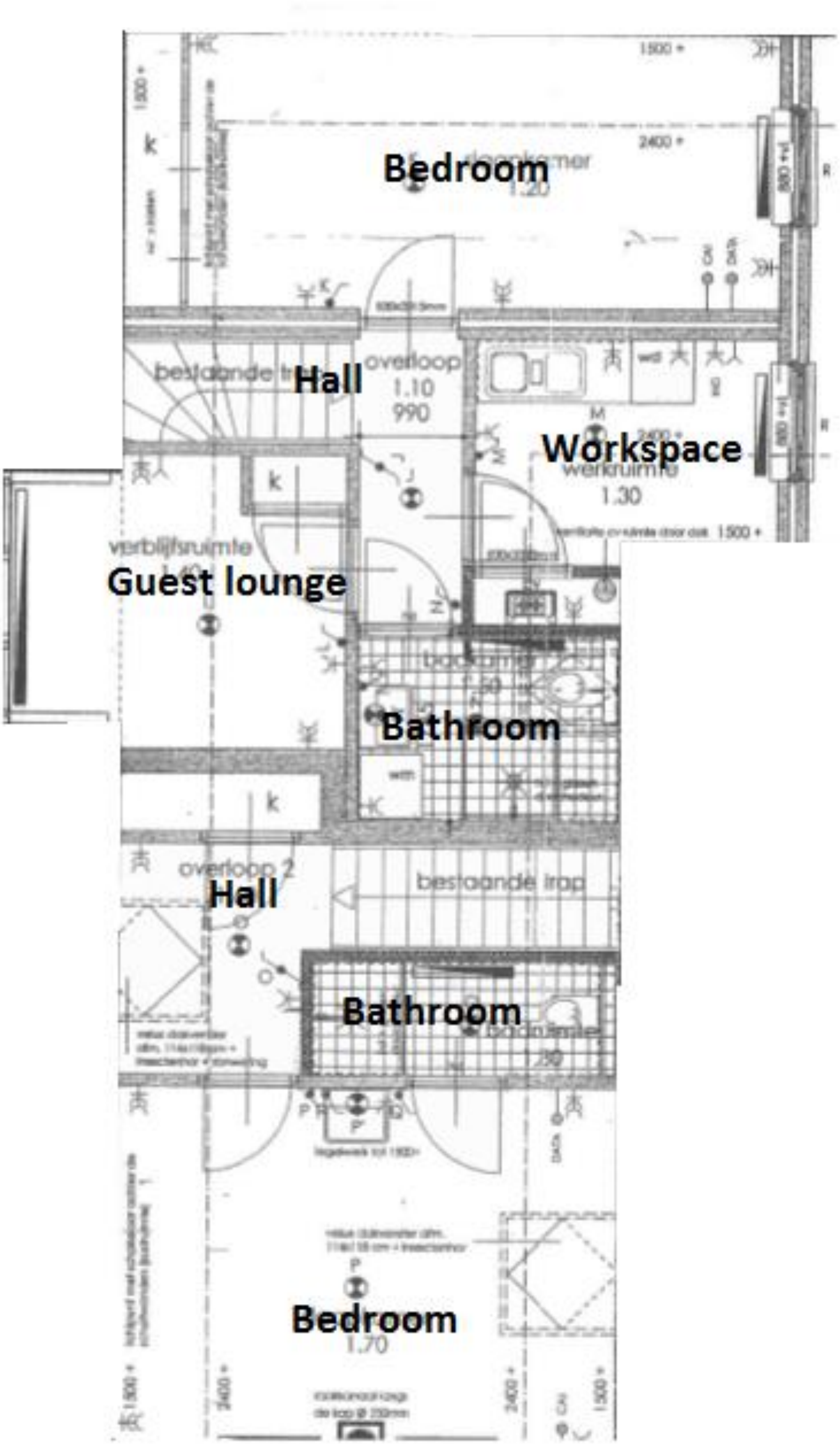
Dwelling:



Floor plan ground floor

Dwelling:

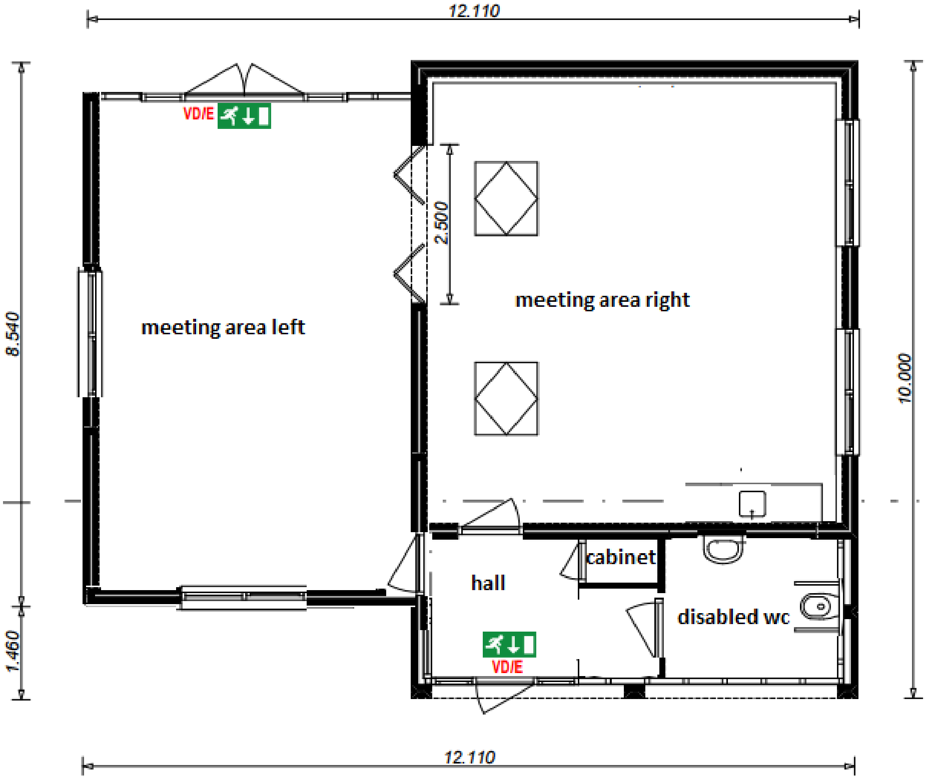


Floor plan second floor

Dwelling:

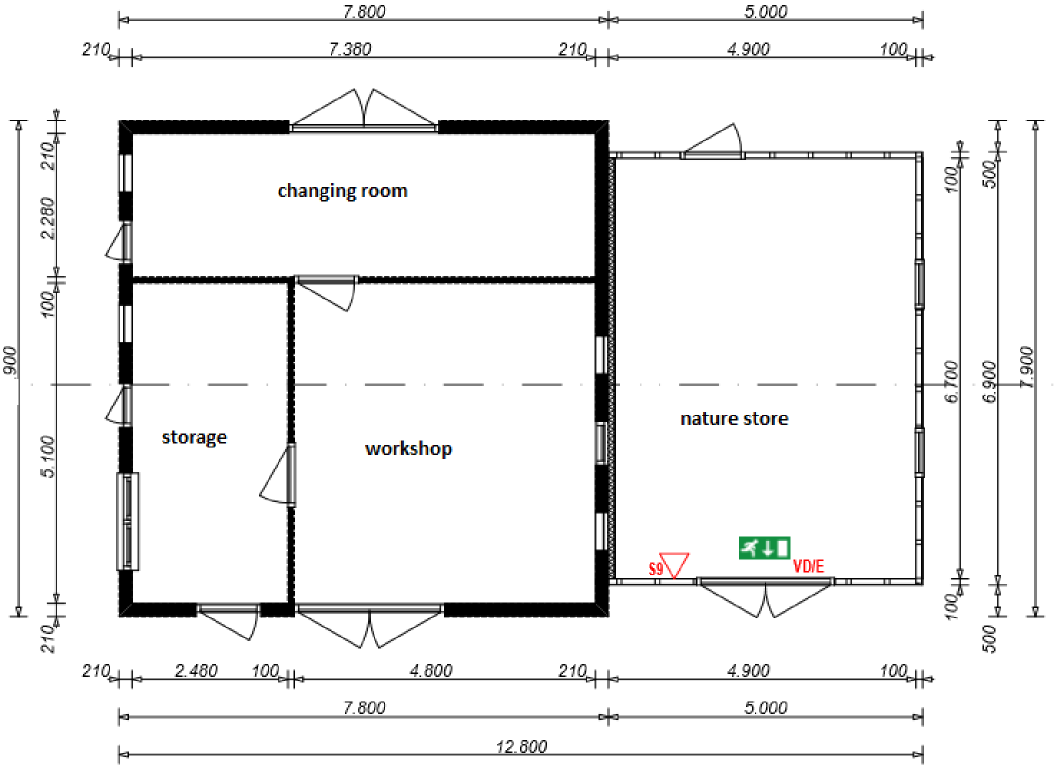
Photograph front view

Meeting area:



Floor plan

Nature shop with work shed and changing room:



Floor plan

Nature shop with work shed and changing room:

Photograph front view

Meeting area:

Photograph front view

Stables:

Photograph front view

APPENDIX B: ENERGY BILLS INNOVA ENERGIE BV

Energy bill Innova period December 8, 2014 till November 12, 2015

Network operator	Enexis		
Start and due date	Dec-08-2014	Nov-12-2015	Consumption
Meter high (2)	30473	36772	6299 kWh
Meter low (1)	22957	27268	4311 kWh
Number of days	339	Total use:	10610 kWh
		Consumption 1	**Consumption 2**
12-08-2014 till 01-01-2015		305 kWh	446 kWh
01-01-2015 till 11-12-2015		4006 kWh	5 953 kWh

Network operator	Cogas		
Start and due date	Dec-08-2014	Nov-12-2015	Consumption
Meter reading	14785	17239	2454 m^3
Number of days	339		
Usage after correction*:			2471 m^3
			Consumption
12-08-2014 till 01-01-2015			331 m^3
01-01-2015 till 11-12-2015			2140 m^3

Energy bill Innova period November 12, 2015 till October 17, 2016

Network operator	Enexis		
Start and due date	Nov-12-2015	Oct-17-2016	Consumption
Meter high (2)	36772	42146	5374 kWh
Meter low (1)	27268	30936	3668 kWh
Number of days	340	Total use:	9042 kWh
		Consumption 1	**Consumption 2**
11-12-2015 till 01-01-2016		539 kWh	790 kWh
01-01-2016 till 10-17-2016		3129 kWh	4584 kWh

Network operator	Cogas		
Start and due date	Nov-12-2015	Oct-17-2016	Consumption
Meter reading	17239	19520	2281 m^3
Number of days	339		
Usage after correction*:			2311 m^3
			Consumption
11-12-2015 till 01-01-2016			589 m^3
01-01-2016 till 10-17-2016			1722 m^3

APPENDIX C: METER READINGS

Meter readings period September 5, 2016 till November 14, 2016; usage per day

Date (2016)	E1: low (kWh)	E1: cum (kWh)	E2: normal (kWh)	E2: cum (kWh)	Etot (kWh)	Etot: cum (kWh)	Gas (m^3)	Gas: cum (m^3)	Water (m^3)	Water: cum (m^3)
5-Sep	5	5	12	12	17	17	0,747	0,747	0,47	0,47
6-Sep	3	4	15	13,5	18	17,5	0,561	0,654	1,08	0,78
7-Sep	4	4	16	14,3	20	18,3	1,724	1,011	0,59	0,71
8-Sep	4	4	16	14,8	20	18,8	0,844	0,969	0,83	0,74
9-Sep	5	4,2	16	15	21	19,2	0,676	0,910	0,68	0,73
10-Sep	15	6	0	12,5	15	18,5	1,362	0,986	0,89	0,76
11-Sep	15	7,3	1	10,9	16	18,1	0,849	0,966	0,71	0,75
12-Sep	4	6,9	11	10,9	15	17,8	1,608	1,046	0,60	0,73
13-Sep	5	6,7	15	11,3	20	18	0,649	1,002	0,63	0,72
14-Sep	3	6,3	16	11,8	19	18,1	0,872	0,989	1,13	0,76
15-Sep	3	6	15	12,1	18	18,1	0,673	0,961	0,94	0,78
16-Sep	6	6	13	12,2	19	18,2	0,420	0,915	0,67	0,77
17-Sep	18	6,9	0	11,2	18	18,2	1,402	0,9528	0,86	0,78
18-Sep	16	7,6	1	10,5	17	18,1	0,488	0,9196	0,54	0,76
19-Sep	4	7,3	9	10,4	13	17,7	1,205	0,9387	0,56	0,75
20-Sep	4	7,1	16	10,8	20	17,9	0,708	0,9242	0,84	0,75
21-Sep	3	6,9	15	11	18	17,9	0,735	0,9131	1,18	0,78
22-Sep	4	6,7	20	11,5	24	18,2	2,111	0,9797	1,89	0,84
23-Sep	5	6,6	14	11,6	19	18,3	0,966	0,979	0,52	0,82
24-Sep	21	7,4	0	11,1	21	18,4	1,516	1,006	1,41	0,85
25-Sep	10	7,5	1	10,6	11	18	0,755	0,994	0,37	0,83
26-Sep	4	7,3	15	10,8	19	18,1	0,974	0,993	0,65	0,82
27-Sep	4	7,2	15	11	19	18,1	0,887	0,988	0,64	0,81
28-Sep	4	7	17	11,2	21	18,3	1,423	1,006	0,94	0,82
29-Sep	5	7	16	11,4	21	18,4	1,644	1,032	0,87	0,82
30-Sep	7	7	14	11,5	21	18,5	0,731	1,020	0,54	0,81
1-Oct	16	7,3	0	11,1	16	18,4	1,013	1,020	0,69	0,80
2-Oct	18	7,7	1	10,7	19	18,4	1,586	1,040	0,52	0,79
3-Oct	4	7,6	11	10,7	15	18,3	2,005	1,074	0,34	0,78
4-Oct	2	7,4	15	10,9	17	18,2	2,096	1,108	0,53	0,77
5-Oct	3	7,2	19	11,1	22	18,4	4,906	1,230	0,73	0,77
6-Oct	4	7,1	19	11,4	23	18,5	5,411	1,361	0,67	0,77
7-Oct	7	7,1	19	11,6	26	18,7	3,617	1,429	0,75	0,77
8-Oct	22	7,6	0	11,3	22	18,8	1,555	1,433	0,88	0,77
9-Oct	13	7,7	2	11	15	18,7	3,021	1,478	0,45	0,76
10-Oct	4	7,6	12	11	16	18,6	5,090	1,579	0,45	0,75
11-Oct	3	7,5	20	11,3	23	18,8	10,393	1,817	1,06	0,76
12-Oct	3	7,4	15	11,4	18	18,7	4,676	1,892	0,40	0,75
13-Oct	2	7,2	21	11,6	23	18,8	6,260	2,004	0,63	0,75

14-Oct	4	7,2	16	11,7	20	18,9	5,130	2,082	0,63	0,74
15-Oct	21	7,5	0	11,4	21	18,9	5,281	2,160	0,82	0,75
16-Oct	15	7,7	1	11,2	16	18,9	0,740	2,126	0,38	0,74
17-Oct	3	7,6	11	11,2	14	18,7	3,889	2,167	0,50	0,73
18-Oct	3	7,5	21	11,4	24	18,9	5,927	2,253	0,71	0,73
19-Oct	3	7,4	18	11,6	21	18,9	7,027	2,359	0,68	0,73
20-Oct	5	7,3	21	11,8	26	19,1	8,637	2,495	0,95	0,73
21-Oct	5	7,3	15	11,8	20	19,1	7,696	2,606	0,71	0,73
22-Oct	22	7,6	0	11,6	22	19,1	8,581	2,731	0,74	0,73
23-Oct	10	7,6	1	11,4	11	19	6,300	2,803	0,25	0,72
24-Oct	3	7,5	12	11,4	15	18,9	8,500	2,917	0,77	0,72
25-Oct	4	7,5	25	11,6	29	19,1	10,440	3,065	1,07	0,73
26-Oct	3	7,4	23	11,9	26	19,2	9,877	3,120	0,80	0,73
27-Oct	3	7,3	17	12	20	19,2	7,592	3,279	0,59	0,73
28-Oct	5	7,2	15	12	20	19,3	5,975	3,329	0,76	0,73
29-Oct	11	7,3	0	11,8	11	19,1	6,650	3,389	0,80	0,73
30-Oct	15	7,4	1	11,6	16	19,1	3,345	3,388	0,57	0,73
31-Oct	4	7,4	7	11,5	11	18,9	3,959	3,398	0,48	0,73
1-Nov	3	7,3	14	11,6	17	18,9	10,178	3,515	0,77	0,73
2-Nov	5	7,3	10	11,5	15	18,8	10,796	3,639	0,39	0,72
3-Nov	3	7,2	13	11,6	16	18,8	8,636	3,722	0,82	0,72
4-Nov	5	7,2	10	11,5	15	18,7	7,886	3,790	0,58	0,72
5-Nov	16	7,3	0	11,4	16	18,7	11,825	3,920	0,92	0,72
6-Nov	14	7,4	0	11,2	14	18,6	3,172	3,908	0,54	0,72
7-Nov	2	7,3	13	11,2	15	18,5	10,281	4,007	0,32	0,71
8-Nov	3	7,3	15	11,3	18	18,5	18,281	4,227	0,53	0,71
9-Nov	3	7,2	14	11,3	17	18,5	16,142	4,408	0,72	0,71
10-Nov	3	7,1	19	11,4	22	18,6	15,026	4,566	0,76	0,71
11-Nov	3	7,1	10	11,4	13	18,5	14,707	4,715	0,57	0,71
12-Nov	18	7,2	0	11,2	18	18,5	18,386	4,913	0,86	0,71
13-Nov	13	7,3	1	11,1	14	18,4	11,470	5,007	0,48	0,71
14-Nov	4	7,3	19	11,2	23	18,5	13,749	5,130	0,31	0,70

Meter readings period November 17, 2016 till December 22, 2016 at 09:00 AM

Date (2016)	Day	Electricity 1 (kWh)	Electricity 2 (kWh)	Natural gas (m^3)	Water (m^3)
17-Nov	Thursday	31154	42503	19814,98	1723,719
18-Nov	Friday	31157	42516	19826,43	1724,617
19-Nov	Saturday	31161	42528	19843,81	1725,29
20-Nov	Sunday	31188	42528	19848,42	1726,249
21-Nov	Monday	31205	42529	19855,24	1726,663
22-Nov	Tuesday	31208	42541	19865,47	1727,033
23-Nov	Wednesday	31211	42555	19873,17	1727,703

24-Nov	Thursday	31215	42567	19881,96	1728,114
25-Nov	Friday	31219	42583	19894,38	1729,312
26-Nov	Saturday	31224	42594	19906,5	1730,028
27-Nov	Sunday	31244	42594	19925,42	1730,763
28-Nov	Monday	31256	42595	19928,28	1731,282
29-Nov	Tuesday	31259	42595	19942,25	1731,609
30-Nov	Wednesday	31263	42619	19966,09	1732,094
1-Dec	Thursday	31265	42636	19988,92	1732,976
2-Dec	Friday	31268	42656	20002,52	1733,725
3-Dec	Saturday	31272	42671	20012,25	1734,558
4-Dec	Sunday	31290	42671	20026,34	1735,085
5-Dec	Monday	31299	42672	20038,38	1735,478
6-Dec	Tuesday	31303	42685	20060,56	1736,047
7-Dec	Wednesday	31306	42697	20083,09	1736,892
8-Dec	Thursday	31309	42715	20095,07	1737,883
9-Dec	Friday	31313	42732	20108,5	1738,539
10-Dec	Saturday	31319	42753	20122,15	1739,376
11-Dec	Sunday	31337	42753	20129,8	1740,029
12-Dec	Monday	31348	42754	20137,02	1740,467
13-Dec	Tuesday	31352	42765	20150	1740,847
14-Dec	Wednesday	31355	42784	20165,61	1741,598
15-Dec	Thursday	31358	42804	20177,38	1742,192
16-Dec	Friday	31363	42826	20193,5	1713,167
17-Dec	Saturday	31369	42835	20201,41	1743,727
18-Dec	Sunday	31384	42835	20211,85	1744,552
19-Dec	Monday	31402	42837	20218,42	1744,979
20-Dec	Tuesday	31406	42852	20235,32	1745,497
21-Dec	Wednesday	31410	42870	20261,18	1746,156
22-Dec	Thursday	31415	42887	20276,33	1746,888

Meter readings period after December 22 (inclusive holiday) at 09:00 AM, 2016;2017

These meter readings are not included in the research because of the holiday (the social care farm was closed a week) and the start of a new year (2017), but it might be interesting for other studies.

Date (2016/2017)	Day	Electricity 1 (kWh)	Electricity 2 (kWh)	Natural gas (m^3)	Water (m^3)
23-Dec	Friday	31418	42911	20291,600	1747,825
24-Dec	Saturday	31425	42931	20308,724	1748,642
25-Dec	Sunday	N.A.N.	N.A.N.	N.A.N.	N.A.N.
26-Dec	Monday	31468	42931	20320,742	1749,902
27-Dec	Thuesday	31483	42932	20330,166	1750,302
28-Dec	Wednesday	N.A.N.	N.A.N.	N.A.N.	N.A.N.
29-Dec	Thursday	N.A.N.	N.A.N.	N.A.N.	N.A.N.
30-Dec	Friday	N.A.N.	N.A.N.	N.A.N.	N.A.N.

31-Dec	Saturday	31498	42953	20350,570	1751,118
1-Jan	Sunday	31520	42953	20376,572	1751,749
2-Jan	Monday	31535	42955	20402,536	1752,267
3-Jan	Thuesday	31538	42966	20415,816	1752,504
4-Jan	Wednesday	31541	42984	20434,650	1753,450
5-Jan	Thursday	31546	42998	20454,313	1754,444
6-Jan	Friday	31549	43017	20474,280	1755,126
7-Jan	Saturday	N.A.N.	N.A.N.	N.A.N.	N.A.N.
8-Jan	Sunday	31584	43038	20511,313	1756,749
9-Jan	Monday	31600	43039	20524,850	1757,324
10-Jan	Tuesday	31605	43051	20540,360	1757,747
11-Jan	Wednesday	31607	43039	20524,850	1757,324
12-Jan	Thursday	31610	43085	20573,645	1758,951
13-Jan	Friday	N.A.N.	N.A.N.	N.A.N.	N.A.N.
14-Jan	Saturday	31618	43112	20603,517	1760,339
15-Jan	Sunday	31635	43112	20623,065	1760,710
16-Jan	Monday	31653	43114	20644,500	1761,462
17-Jan	Tuesday	31658	43123	20664,217	1761,822
18-Jan	Wednesday	31660	43138	20689,000	1762,591
19-Jan	Thursday	31665	43157	20713,795	1763,144
20-Jan	Friday	31668	43173	20740,492	1763,907
21-Jan	Saturday	31672	43183	20759,550	1764,362
22-Jan	Sunday	31685	43183	20774,345	1764,670
23-Jan	Monday	31700	43185	20797,677	1765,070
24-Jan	Tuesday	31704	43197	20823,982	1765,670
25-Jan	Wednesday	31708	43216	20855,626	1766,420
26-Jan	Thursday	31711	43227	20874,974	1767,221
27-Jan	Friday	31714	43240	20899,199	1767,811
28-Jan	Saturday	31721	43250	20918,620	1768,528
29-Jan	Sunday	31731	43250	20924,909	1768,629
30-Jan	Monday	31741	43251	20938,343	1769,178
31-Jan	Tuesday	31751	43265	20956,762	1769,692
1-Feb	Wednesday	31755	43282	20977,120	1770,421
2-Feb	Thursday	31758	43295	20995,415	1771,183
3-Feb	Friday	31763	43305	21006,459	1772,309

Meter readings period November 17, 2016 till November 24, 2016 at openings/closing times

Day/Date/Time	Electricity 1 (kWh)	Electricity 2 (kWh)	Natural gas (m³)	Water (m³)
Thursday 11-17 09:00	31154	42503	19814,98	1723,719
Thursday 11-17 16:30	31154	42511	19819,79	1724,242
Friday 11-18 09:00	31157	42516	19826,43	1724,617
Friday 11-18 16:30	31157	42523	19832,43	1724,848
Saturday 11-19 09:00	31161	42528	19834,81	1725,290
Saturday 11-19 10:00	31162	42528	19836,62	1725,341
Saturday 11-19 16:30	31168	42528	19840,93	1725,952
Sunday 11-20 09:00	31188	42528	19848,42	1726,249
Sunday 11-20 16:30	31196	42528	19854,49	1726,480
Monday 11-21 09:00	31205	42529	19855,74	1726,663
Monday 11-21 16:30	31205	42536	19862,78	1726,834
Tuesday 11-22 09:00	31208	42541	19865,47	1727,033
Tuesday 11-22 16:30	31208	42548	19867,69	1727,374
Wednesday 11-23 09:00	31211	42555	19873,17	1727,763
Wednesday 11-23 16:30	31211	42562	19876,97	1728,153
Thursday 11-24 09:00	31215	42567	19881,96	1728,114

APPENDIX D: METHODS TO MEASURE ELECTRICAL APPLIANCES

Microwave
The fitted kitchen in the meeting area contains a combi microwave that only uses the microwave mode due to the presence of a furnace. The model is an Amica EMW 13190 E with a magnetron power level of 800 Watt. The time of warming is pre-set to 100 seconds and the magnetron is on average ± 1 time in operation during opening hours. Therefore, the weekly electricity usage of the magnetron is 0,11 kWh.

Boiler
The boiler for domestic hot water and heating is located in the attic. Frequently it is forgotten that a boiler also consumes electricity. The model of the boiler is an Intergas Kombi Kompact HRE 28/24 CW4. This model has an annual energy consumption (AEC) of 17 kWh (Radiatorendiscounter, 2016). Since this consumption is not distributed proportionally over the year, the table for the heating days is used. A week in November uses 2% of the total energy usage in a year (Weerstation Uithuizermeeden, 2015). This is equivalent to 0.34 kWh per week.

Ventilation toilet
The ventilation system of the toilet is in correlation with the length of stay of a toilet visit. The ventilation system is in operation when the lamp, in the restroom, is turned on. The residence time in the toilet is on average 2 minutes (see section water consumption Alldrik). The total residence time for a week is 212 minutes. The ventilation in the toilet is driven by a duct fan (VKOT 150) with a power of 24 Watt.

Vacuum cleaner
In a study on the efficiency of vacuum cleaners, twelve professional cleaners vacuumed at a imposed pace that anyone can sustain for eight hours. The productivity of the upright vacuum cleaner was 7,23 m² per minute (Clark & Mengelkoch, 2006). The total surface being cleaned by the vacuum cleaner is 137,31 m^2 (meeting area and nature shop). De used vacuum cleaner is a Miele Complete C2 Black EcoLine with a maximum power of 800 W. When connecting the Watt-hour meter, a maximum power of 775 W appeared. The surface is cleaned two times a week; this equates to $\frac{137,31\ x\ 2}{7,23\ x\ 60}$ x 775 = 0,49 kWh

Built-in refrigerator and freezer dwelling
The dwelling has a built-in refrigerator and freezer which are also used during the opening hours of Alldrik. The refrigerator is a Küppersbursch of 7 years without any further information. There is chosen to compare the refrigerator with a similar type and brand in order to obtain information. There is chosen for the Küppersbusch IKEF 3290-1 of the same size (about 540 x 1773 x 549 mm), with energy label A + and an annual usage of 172 kWh (Küppersbusch, 2016). Alldrik is 36.5 hours a week in operation, so the usage of the refrigerator on a weekly basis is 0.72 kWh. For the freezer is chosen for the Küppersbusch ITE 2390-2 of the same size (about 540 x 1773 x 549 mm), with energy label A + and an annual usage of 321 kWh (Küppersbusch, 2016). The usage of the freezer is 1.34 kWh per week.

Induction cooker and extractor fan

The present induction cooker in the meeting area is a Schott Ceran glass-ceramic cooktop (58x51 cm). This cooktop has four different cooking zones (Figure 24) and ten cooking levels (1 = low; 10 = high). Zone 1 and 4 are similar and have a maximum power of 1,4 kW and zone 2 and 3 are similar with a maximum power of 3,0 kW (Kookplaatstore, 2016). According to the manual, the power is distributed uniform over the cooking levels. To determine the electricity usage of the cooker, the cooking sessions during the measurement week (November 17th till November 24th) are accurately observed. The total electricity used by the induction cooker is 7,236 kWh per week (Table 41). It is assumed that extractor fan is in operation during the cooking activity. Therefore, the electric power use of the extractor fan is the number of cooking hours times the power. The total number of cooking hours can be deduced from Table 41 and is equal to four hours and twenty minutes. The engine in the extractor fan has a power of 105 W according to the manufacturer's label. The total electric power usage of the extractor fan is 456 kWh per week.

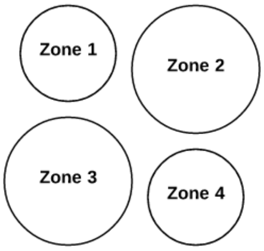


Figure 24: cooking zones induction cooker meeting area Alldrik

Table 41: cooking scheme Alldrik in the period between November 17th - November 23th, 2016

Day/date	Zone	Period	Level	Usage (Wh)	Total usage
Thursday 17-11	1	11:20-11:50; 12:05-12:20; 12:20-12:45	5; 6; 1	350; 175; 58,3	0,583 kWh
	2	11:20-12:20; 12:20-12:45	2; 1	600; 125	0, 725 kWh
	3	11:15-11:40; 12:05-12:20; 12:20-12:45	3; 2; 1	375; 150; 125	0,65 kWh
Friday 18-11	1	11:25-11:45	5	233,3	0,233 kWh
	3	11:10-11:30; 11:30-11:55; 11:55-12:00; 12:00-12:15	8; 2; 3; 7	800; 250; 75; 525	1,65 kWh
	4	11:25-11:30; 11:30-11:35; 11:35-11:55; 11:55-12:35	8; 7; 3; 1	93,3; 81,67; 140; 93,3	0,408 kWh
Tuesday 22-11	1	11:10-11:25; 11:25-11:50	6; 3	210; 175	0,385 kWh
	2	11:25-11:35	4;	200	0,2 kWh
	3	11:25-11:30; 11:30-11:45; 11:45-11:55	6; 4; 3	150; 300; 150	0,6 kWh
Wednesday 23-11	2	11:20-11:35; 11:35-11:45; 11:45-11:55; 11:55-12:35	5; 6; 3; 2	375; 300; 150; 400	1,225 kWh
	3	11:45-12:35	1	250	0,25 kWh
	4	11:45-11:55; 11:55-12:15; 12:15-12:30	5; 3; 2	116,67; 140; 70	0,327 kWh

APPENDIX E: ARCHITECTURAL CHARACTERISTICS MEETING AREA ALLDRIK

Floor

The meeting area is built on an insulated concrete floor with a frosted edge. The concrete floor has a thickness of 120 mm and is equipped with a single steel mesh of ø 8-150 mm. Below the concrete floor and around the frosted edge is insulation with a R_c-value of 2,5. The ground floor is provided with a sand-cement screed with a thickness of 50 mm.

Thickness (mm)	Materials	Thermal resistance ($m^2 \cdot K/W$)	Thermal conductivity ($W/(m \cdot K)$)	Density (kg/m^3)	Specific heat ($J/(kg \cdot K)$)
50	Concrete – screed	(-)	1,300	2000	840
120	Concrete – steel mesh	(-)	1,900	2500	840
65	Insulation - sethaan	(-)	0,027	30	1470

Roof

The roof structure of the meeting area is composed of planed fire timber, namely trusses (71x196 mm) and purlins (59x156 mm). An insulation plate of 60 mm with plastic H-profiles is applied on the purlins. The insulation plate has a R_c-value of 2,5. Over the insulation are battens applied for the purpose of the corrugated sheets. The wind springs of the are conducted in red cedar wood buoy parts with a thickness of 18 mm. The overhangs are conducted in garantplex with a thickness of 10 mm. A ventilated battening is applied on these overhangs. The roof is made of anthracite-coloured corrugated sheets, including hinged ridge pieces. The corrugated sheets are being pinned by three-piece stainless steel corrugated screws.

Thickness (mm)	Materials	Thermal resistance ($m^2 \cdot K/W$)	Thermal conductivity ($W/(m \cdot K)$)	Density (kg/m^3)	Specific heat ($J/(kg \cdot K)$)
65	Insulation – sethaan	(-)	0,027	30	1470
28	Cavity -diagonal	0,090	(-)	(-)	(-)
37	Metal - steel	(-)	41,000	7800	480

Frames, windows, and doors

The outside frames, including windows, and doors are made of hardwood, The windows in Mahoney and the doors in Merbau. The frames of windows and doors are factory coated with a primer with a 110 mu thickness. Both the exterior and interior doors have a thickness of 70 mm.

Window – frame data	(-)
Frame surface percentage	5%
Frame type	Wood
U-frame	2,40 $W/(m^2 \cdot K)$
Ψ-value	0,08 $W/(m \cdot K)$

Thickness (mm)	Materials	Thermal resistance ($m^2 \cdot K/W$)	Thermal conductivity ($W/(m \cdot K)$)	Density (kg/m^3)	Specific heat ($J/(kg \cdot K)$)
70	Wood – hardwood	(-)	0,170	800	1880

Glazing

The glass apertures are provided with HR ++ glazing.

Window – glass data	(-)
Glass type	HR++ glass
Ug value	1,10 $W/(m^2 \cdot K)$
Solar factor, g (45°)	0,58

External facade

The external facade consists of rough Douglas planks (20 mm), plasterboard (13 mm), a vapor barrier foil, battering, insulation (95 mm), vapor permeable foil, ventilation slats and again rough Douglas planks (20 mm) in an untreated embodiment.

Thickness (mm)	Materials	Thermal resistance (m^2· K/W)	Thermal conductivity (W/(m· K)	Density (kg/m^3)	Specific heat (J/(kg · K))
20	Wood – coniferous	(-)	0,140	550	1880
13	Plate -plasterboard	(-)	0,230	900	850
38	Cavity – horizontal	0,160	(-)	(-)	(-)
95	Insulation – sethaan	(-)	0,027	30	1470
20	Wood - coniferous	(-)	0,140	550	1880

Interior wall

The interior walls consist of a two-sided plasterboard (12,5 mm) screwed onto a dim spruce wood battening with insulation between the battening (90 mm).

Thickness (mm)	Materials	Thermal resistance (m^2· K/W)	Thermal conductivity (W/(m· K)	Density (kg/m^3)	Specific heat (J/(kg · K))
12,5	Plate – plasterboard	(-)	0,230	900	840
95	Insulation – sethaan	(-)	0,027	30	1470
12,5	Plate – plasterboard	(-)	0,230	900	840

Panel

The panel between the two meeting area is made from a two-sided polyester plate (8 mm) with PUR (44 mm) between the plates.

Thickness (mm)	Materials	Thermal resistance (m^2· K/W)	Thermal conductivity (W/(m· K)	Density (kg/m^3)	Specific heat (J/(kg · K))
8	Plate -polyester plate	(-)	0,200	1200	1470
44	Insulation - PUR	(-)	0,030	30	1470
8	Plate – polyester plate	(-)	0,200	1200	1470

APPENDIX F: ARCHITECTURAL CHARACTERISTICS DWELLING ALLDRIK

Floor

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
50	Concrete – screed	(-)	1,300
400	Concrete – steel mesh	(-)	1,900
80	Insulation – EPS	(-)	0,035

Interior floor

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
50	Concrete – screed	(-)	1,300
70	Concrete – topping	(-)	1,800
1	Concrete – hollow core slab	(-)	2,000
250	Cavity – horizontal	0,160	(-)
13	Plate - plasterboard	(-)	0,230

Roof

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
15	Roof - tile	(-)	0,650
44	Cavity - diagonal	0,090	(-)
8	Plate – hardboard	(-)	0,290
100	Insulation – mineral wool	(-)	0,035
13	Plate - plasterboard	(-)	0,230

Frames and windows

Window – frame data	(-)
Frame surface percentage	5%
Frame type	Wood
U-frame	2,40 W/(m²· K)
Ψ-value	0,08 W/(m· K)

exterior door

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
70	Wood – hardwood	(-)	0,170

Interior door

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
40	Plate - particleboard	(-)	0,100

Glazing

The glass apertures are provided with HR ++ glazing.

Window – glass data	(-)
Glass type	HR++ glass
Ug value	1,10 W/(m²· K)
Solar factor, g (45°)	0,58

External facade

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
20	Masonry – bricks	(-)	0,800
13	Cavity – vertical	0,180	(-)
38	Insulation – mineral wool	(-)	0,035
95	Masonry – limestone	(-)	1,000
20	Plate - plasterboard	(-)	0,230

Interior wall

Thickness (mm)	Materials	Thermal resistance (m²· K/W)	Thermal conductivity (W/(m· K)
13	Plate - plasterboard	(-)	0,230
75	Wood - softwood	(-)	0,140
13	Plate - plasterboard	(-)	0,230

APPENDIX G: APPLIED HEATING SYSTEMS ALLDRIK

Heating and domestic hot water meeting area

Name	Intergas Kombi Kompact HRE 28/24 CW4
System	Combi heat generator for heating and domestic hot water
Type	Combi boiler (gas)
Lower modulation	Yes
Heat certificate	High efficiency 107 boiler
Certificate domestic hot water	CW
Application class	Comfort class 4
Thermal power	23 kW
Supply temperature	70°C
Return temperature	60°C
Ambient temperature	19,5°C
Conversion efficiency	94%
Efficiency domestic hot water	85%
Annual energy consumption (AEC)	17 kWh

Heating and domestic hot water dwelling

Name	Nefit Topline Aquapower 2 HRC 25/CW4
System	Combi heat generator for heating and domestic hot water
Type	Combi boiler (gas)
Lower modulation	Yes
Heat certificate	High efficiency 107 boiler
Certificate domestic hot water	HRww
Application class	Comfort class 4
Thermal power	23,3 kW
Supply temperature	70°C
Return temperature	60°C
Ambient temperature	19,5°C
Conversion efficiency	98,5%
Efficiency domestic hot water	88,4%
Annual energy consumption (AEC)	48 kWh