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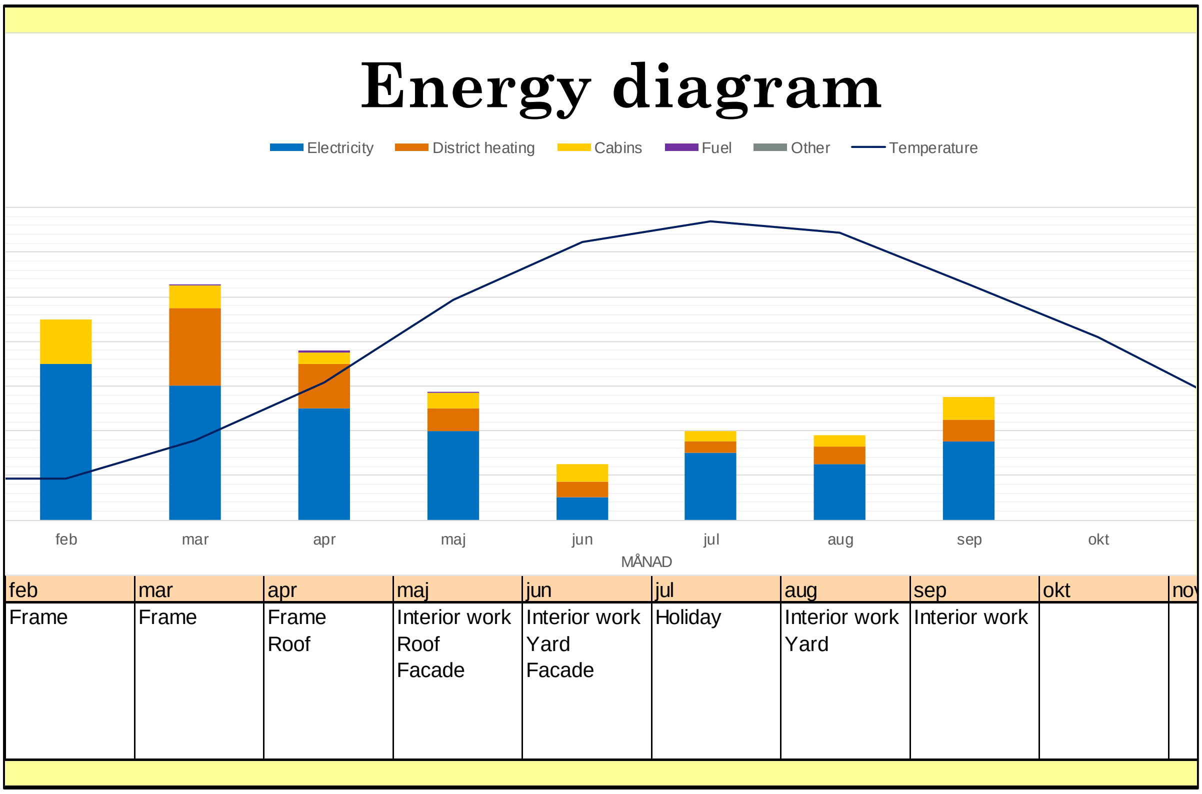

ENKLA - Energy Mapping Model for the Construction of Apartment Buildings

A Method proposal for Peab Construction

Master's Thesis in the Master's Programme Structural Engineering and Building Technology

RONJA ARVIDSSON
MADELEINE FAHLSTRÖM

Department of Civil and Environmental Engineering
Division of Building Technology
Building Physics Modelling
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Department of Civil and Environmental Engineering
Division of Building Technology
Building Physics Modelling
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover:
The picture presents a part of the developed diagram in ENKLA, showing the variation of energy consumption throughout a house construction.

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ABSTRACT

The law of *Energy audit in large companies* came into force in Sweden the year of 2014, as a response to the EU's developed Energy-Efficiency Directive. However, the law is not clear for companies such as the construction companies, because of their dispersed operations of both offices and construction sites. One of these companies, Peab, expressed a help on how to identify energy out on the building construction site, as it was unclear in the law how this task should be accomplished. That is where this thesis comes into the picture.

The goal of this thesis is to develop a model that will help Peab to map out their energy usage at the construction site for the erection of houses. The thesis process started with a literature study, to find out more about the law and its background. As there were no clear guidelines on how to proceed in the mentioned problem, the process was made by trying different approaches until a workable method was found. This was done through a number of site visits to the chosen case study, the project Landningsbanan, as well as tutorials and meetings with workers at Peab. When the first draft of a model was produced, further investigations were made of how it could be developed to a useful and beneficial tool for Peab. The resulting model, made in Excel, should be easy to use and not cause any greater workload, this in order to expand the possibilities that it actually will be used. Hence, it got the suitable name ENKLA, (Energy Mapping Analysis), which is the Swedish word for easy.

In ENKLA information about the current project is to be filled in, the values of energy used and its cost based on bills, as well as which part of the building process that is current during the given month. The model will then present results in different units in both table and graph form, to be useful for many different roles within the company. Another application of the model is to predict energy consumption by inserting possible values, before a project has started. ENKLA is useful both for energy mapping of various projects and to find possible energy efficiency measures. A further thought with ENKLA is to collect measured values from different projects and thereby to provide a database with expected values from projects of house production for Peab Construction. With the standard values the expected energy consumption can be estimated from the very beginning in a project.

Keywords: Energy audit, Energy mapping model, Energy-efficiency directive, construction energy, energy efficiency.

ENKLA - Energi Kartläggnings Modell anpassad för Bostadsproduktion
Ett Metod förslag åt Peab Bygg

Examensarbete inom masterprogrammet Structural Engineering and Building Technology

RONJA ARVIDSSON
MADELEINE FAHLSTRÖM
Institutionen för bygg- och miljöteknik
Avdelningen för Byggnadsteknologi
Byggnadsfysikalisk modellering
Chalmers tekniska högskola

SAMMANFATTNING

Lagen om *Energikartläggning i stora företag* trädde i kraft år 2014 i Sverige, som en respons på EU:s framtagna energieffektiviserings direktiv EED. Lagen säger bland annat att stora företag ska kartlägga all årlig förbrukad energi och komma fram till energieffektiviseringsåtgärder. Detta är dock inte helt enkelt för alla företag såsom byggföretag, som har en spridd verksamhet av både kontor och ett flertal byggarbetsplatser. Ett av dessa företag är Peab, vilka frågade om vägledning för hur de ska kartlägga energin ute på byggarbetsplatserna, då det var oklart hur de skulle angripa problemet. Utifrån den frågan kommer detta examensarbete in i bilden.

Målet med examensarbetet är att ta fram en modell som ska hjälpa Peab att kartlägga den energi som de gör av med på byggarbetsplatsen vid produktion av bostäder. Hela arbetet började med en litteratur studie, för att ta reda på mer om lagen och dess bakgrund. Då det inte fanns några klara riktlinjer i hur energikartläggning skulle gå tillväga inom byggsektorn, prövades ett flertal olika tillvägagångssätt fram tills en fungerande metod var funnen. Detta gjordes genom platsbesök på ett valt bostadsprojekt vid namn Landningsbanan, samt med handledning och möten med arbetare på Peab. När ett första utkast var framtaget av en modell som levde upp till lagen, gjordes vidare undersökningar hur den skulle kunna utvecklas till ännu större nytta för Peab. Den resulterande modellen är gjord i Excel eftersom den anses behöva vara enkel om den skulle kunna åtas. Därmed också det passande namnet ENKLA.

När ett projekt ska studeras i ENKLA, fylls information i gällande var projektet byggs geografiskt samt stommaterial och antal lägenheter. Därefter ska värden fyllas i om den använda energiförbrukningen och dess tillhörande kostnad baserade på fakturor, samt vilken del i byggprocessen som är under produktion, detta för respektive månad. Modellen presenterar sedan resultat i olika enheter i både tabell- och diagramform, för att vara till nytta för flera olika roller inom företaget. Det finns även möjlighet att fylla i värden om förutspådd energiåtgång innan ett projekt har dragit igång. Utifrån detta är ENKLA sedd som användbar både för energikartläggning och för att hitta möjlig energieffektivisering, vilka är utifrån både lagens och företagets intresse.

Nyckelord: Energikartläggning, Energikartläggningsmodell, Energi Effektiviserings Direktiv, Peab, byggarbetsplatsenergi, energieffektivisering.

Contents

Preface

In this Master thesis, a model for energy mapping a building contractor's construction sites energy consumption has been developed with the intention to be a help for the company to fulfil the Energy audit law. The thesis was carried out from January to June 2016 at Chalmers University of Technology, Department of Civil and Environmental Engineering, Division of Building Technology within the Master's Programme Structural Engineering and Building Technology. The study was made in a cooperation with the company Peab.

The thesis has been a cooperation between the two authors Ronja and Madeleine, were discussion has been an important part in the progress in order to come up with the final result. Ronja has been responsible of creating and developing the model with parameters, outlook, equations and functionality. Madeleine has done research of the Energy Audit law, its background, what it compiles, how it should be applied in the construction industry and what it means for this study.

Special thanks goes to our supervisors at Peab Jan-Erik Lindberg, KMA coordinator, and Kristina Gabrielli, sustainability manager, for supporting and providing us with good spirit. We also want to thanks the site management at the project Landningsbanan, especially Jonas Persson, the site manager, and Henrik Borg, work supervisor, for taking your time to answer our cumbersome questions and their good tune. A big thanks to our supervisor and examiner Angela Sasic Kalagasidis, Associate Professor at Chalmers, for supporting us. Warm thanks to our opponents Lovisa Waldenström and Sara Eriksson, for supporting each other and having meaningful discussions throughout this thesis. And finally warm thanks to you all at Peab, for the pleasant time at your office.

Göteborg, June 2016

Ronja Arvidsson
Madeleine Fahlström

Notations

This section presents and clarifies words used in the report. The words are listed alphabetically.

Approach:	Refers to how this thesis has been carried out.
BoA:	The living area of a building.
BTA:	The gross total area of a building.
EED:	The Energy Efficiency Directive.
Energy audit:	The word considers the energy audit law.
Energy mapping:	The part of the energy audit law, where energy is meant to be mapped.
ENKLA:	The developed energy mapping model.
Frame:	The load bearing system of a construction.
Method:	Refers to the found and proposed way of how to sort and collect data into the model.
Model:	The Excel file where collected data is placed and sorted.
The concept:	The idea of the method and model combined.

1 Introduction

This chapter presents the background to why this thesis has been carried out, followed by its purpose and limitations. Furthermore, this chapter ends with an overview of the used approaches in this work.

The European Union (EU) has decided that one goal to achieve a sustainable global climate is through energy efficiency. The year of 2012, a directive was made by EU with the goal to decrease the energy usage within the EU countries by 20 % until the year of 2020. From this goal the energy audit law in Sweden was established.

The energy audit law, mediated through the Swedish Ministry of Energy Energimyndigheten, states that all large companies needs to map their energy and come up with energy efficiency measurements. This affects the company Peab and their business area construction. In this area it is not seen as an easy task to map their energy because of the differences between project's, their construction sites varieties and the great number of projects all over the country.

This thesis is therefore made to investigate how an energy mapping can be done practically, i.e. by using a model that would resolve the used energy at a construction site along with the energy consuming activities. Since no model is available today, there is a need of a model which enables Peab Construction to find energy efficient measurements.

1.1 Purpose

The purpose of this thesis's is to create a general model of energy mapping suitable for the construction period for Peab Construction. In order to make a model for energy mapping at the construction site, answers for the following questions were needed:

- What does the energy audit law mean for the house construction industry?
- What knowledge about the construction site are needed in order to create the model?
- How could a general energy mapping model look like?
    - Which energy parameters should be included?
- Who will use the model and where should it be implemented?

1.2 Limitations

The energy audit law concerns the whole company, but this project focus only on the business area Peab Construction and their responsible energy consumption at the construction site. To be more specific, Peab Construction is responsible for all energy they pay for, which includes the energy carriers for instance electricity, fuel and district heating. The fuel used for transportation to and from the site and energy paid by subcontractors' is therefore not considered, which is according to the law. Since the law includes several aspects such as energy consumption and the cost, the main focus has been on how to map the energy.

The case study is firstly made from one of Peab's construction project in the Gothenburg area in order to come up with a first draft of the model.
From there the model has been developed further with help of four other construction projects, all of them located in the Gothenburg area as well.

1.3 Method

When planned this thesis time-plan, a Gantt-scheme was used where every step of the work was listed and followed each week. By reflecting of what the work could mean for the final outcome, the focus in the end of the thesis became clearer. Overall the timeframe was useful since the scheme visually showed the timeframe and what part of the thesis should be made at what time. This structure has been both useful and considered as an important part of the thesis's development.

The thesis started with a literature study to get background information about the energy audit law, what has previously been done within the subject and especially in the house construction industry. In the literature study a table called the *Construction part table* was discovered, and was further developed into the *Energy part table* with the purpose to investigate all energy needed in the project's different activities. This became this thesis’s first approach.

In order to fill in the *Energy part table*, site visits were made as to collect information of the site, how the construction is carried out and the used energy. The collected information from the site visits became the basis of developing the table further as to sort out the complexity of the thesis's purpose. When the complexity somewhat was sorted out, the information about used energy from each one of the energy carrier electricity, district heating and fuel was collected from bills and discussed with the site manager. The result from each carrier was assembled in an Excel file with the construction activities from the project’s time-plan. The table in the Excel file complies a complementary energy using diagram making the energy usage more visual.

The data from the project Landningsbanan resulted in a first model for energy mapping gained by the found method of how to collect data from bills and time-plan. To see how useful and functional the method and the model in Excel was, four other projects were analysed in the model. The model was thereafter developed further, to be more general and suitable for more projects.

From there an investigation of how the model could be useful at the office and for who and when was made, and by that investigation the model became developed even further. The model will once a project is finished provide with result of the used energy on the project’s construction site and be a help to find the reasons behind the consumption. When several projects have been studied, the result from them can help Peab to find where they can decrease their energy consumption at the construction sites.

Besides the model, investigations about cabins’ energy usage and the site workers’ apprehension of energy have been made to learn of what else can be improved.

2 Energy efficiency

This chapter aims to introduce the subject energy efficiency by firstly introduce its background from an EU directive and the interpretation of the directive to a law in Sweden, followed by how the energy efficiency has been received in Sweden before and after the established law.

2.1 Energy audit established in an EU directive

EU has for a long time been discussing how a sustainable global climate could be achieved, where one of the goals is to reduce the final or primary energy consumption in the EU countries. In the year of 2007, prognoses were made by EU of how the current primary energy consumption will be developed until the year 2020. Based on these prognoses, the conclusion was that an energy efficiency must increase with 20 percent until the year 2020 in order to decrease the energy consumption sufficiently (European Commission, 2016). Three years later, it was seen that the result of the energy efficiency progress was not enough to reach the goal (Prop. 2011/0172/COD)**.** To accelerate the progress, EU presented a directive in the year 2012 called Energy Efficiency Directive (EED) (European Commission, 2016).

The European Commission has written a report about the EED, divided into several categories which are based on guidelines set by EU. The categories are referred as articles, where one of them concerns energy audit, called *Article 8: Energy audits and energy management systems*. The article has different suggestions of how to carry out an energy audit, and which to use depends on for instance the size of the company and what kind of energy the company primarily uses. Concerning the size, the directive states that only large companies is obligated to perform an energy audit whilst smaller ones only are encouraged. And by the meaning of a large company, the definition is (European Commission, 2013):

- A company with a minimum of 250 employees.
- A company with an annual turnover of no less than 50 million euros per year or balance sheet total of no less than 43 million euros per year.

When it comes to how a large company can carry out an energy audit, they have the article as guidance. Beside these guidelines, there are minimum requirements every country and company must follow set by European Commission described in one of the EED's annexes called Annex IV, which are mainly (Prop. 2012/27/EU):

- Collected energy usage data must be quantifiable.
- Provide a thoroughly evaluation of where and for what reason energy is used within the company.
- Relate if possible to a life-cycle cost analysis.
- By having a general view of the energy consumptions, present the most possible source or sources the company has to increase their energy efficiency.

When it comes to suggestions how a certain industry could perform an energy audit, it is up to each country to decide how to adapt to the EED. The implementation in Sweden will be explained in the next section, with focus on the construction industry.

2.2 Energy audit as a law in Sweden

The energy audit law affects large companies, with the definition described in the previous section and moreover exactly how they are affected will be enlightened in the following section.

2.2.1 The interpretation of the EED by the energy authority

The Swedish law of energy audit, based on the EED, came into force in June 2014 and is maintained by the Swedish authority Energimyndigheten. The authority is working on behalf of the Swedish government and are involved in the international cooperation to reach the climate goals. Through them the law of energy audit is mediated to large companies (Energimyndigheten, 2016).

The law of energy audit implies that large companies shall present the amount of energy they consume over a year. The purpose is to make the company attentive over their energy consumption in order to increase their cost and energy efficiency. The energy audit law follows the guidelines from Annex VI and shall therefore contain the following (Energimyndigheten, 2016):

- The total amount of used energy [MWh] annually in order to operate the company.
- How quantifiable energy are distributed within a company.
- The economic costs of the consumed energy SEK.
- Suggest energy efficient measurements.
- Carry out an energy audit at least every fourth year.

Energimyndigheten (2016) wants a report presenting the total amount of used energy and from which energy carrier, for example electricity, district heating/cooling and fuel. Furthermore, it must be declared the most used energy both by amount and carrier and its potential to be energy efficient, presented both in Swedish crones SEK and megawatt hours [MWh].

2.2.2 The construction industry´s guidelines

Since the sector of house construction in Sweden has a climate impact equivalent of
Since the sector of house construction in Sweden has a climate impact equivalent of
7.3 percent of the total yearly impact in Sweden, an increased energy efficiency within the sector could make a noticeable difference on the climate impact (Naturvårdsverket, 2015).

The interpretation of the energy audit law for a construction company with several different businesses is not yet clarified. However, Energimyndigheten (2015) has given out a handbook containing general guidelines for large companies in Sweden, which can be used until industry-specific guidelines are available (Energimyndigheten, 2015).

One of the guidelines with a great impact on how a construction company chooses to work with energy efficiency is the one referring to that a company must motivate if they choose any limitations concerning their energy audit. Such a limitation could be if a business in the company only represent a minority of the total energy consumption or has a minor possibility to improve the business's energy efficiency. This means a construction company needs to carry out different energy audits, since an energy audit for example offices differs from a construction site. An option is then for the company to distinguish where their energy consumption is the highest and neglect the rest (Energimyndigheten, 2015).

Another guideline which also has a huge influence on construction companies is the one that states a company is only obliged to perform an energy audit of the energy they have an impact on. For example, if electricity at a construction site is paid by the construction company, then that amount of used energy is their responsibility alone, no matter if the company has hired subcontractors using the electricity (Energimyndigheten, 2015).

When construction companies send in their final report of their performed energy audit to Energimyndigheten, data must be quantifiable. These data can be taken from the energy suppliers' bills or reliable data taken from measurements at a construction site (Energimyndigheten, 2015).

Until Energimyndigheten provides with suitable energy audit guidelines specifically to the construction industry, there has been and still are investigations and engagements in Sweden on how to carry out energy efficiency within the construction industry. A few of these engagements will be mentioned in the next section.
The construction industry's engagement in energy efficiency in Sweden
Since EU indicated the need of increase the energy efficiency in 2007, investigations have been carried out in Sweden to find a way of how to increase the energy efficiency in the construction industry. Two of them are presented below, where the first one occurred when only the need of energy efficiency was established in Sweden and the other one occurred after the energy efficiency was interpreted as the energy audit law.

2.3 The construction industry's engagement in energy efficiency in Sweden

Since EU indicated the need of increased energy efficiency in 2007, investigations have been carried out in Sweden to find a way of how to increase the energy efficiency in the construction industry. Two of them are presented below, where the first one occurred when only the need of energy efficiency was established in Sweden and the other one occurred after the energy efficiency was interpreted as a part of the energy audit law.

2.3.1 Investigation before the forthcoming energy audit law

SBUF, shortening for the *Swedish construction development fund*, is an organization that makes researches on behalf of the construction industry (SBUF, 2013a). One of their investigations between August 2010 and September 2011 had the purpose to involve several construction companies to discuss guidelines of how to obtain energy efficient routines at construction sites. This investigation included project studies, workshops and discussions of different topics, where some of the conclusions from the workshop will be mentioned below (SBUF, 2013b).

In order to get knowledge about the energy consumption at a construction site, a few construction projects were selected to take measurements at the sites and in the end provide with an energy ratio. One of the part of the projects' results showed that it was difficult to find a well-working indicator when the projects had differences in for instance geography and the size in terms of [m^3]. Therefore, it was decided that a general energy performance indicator is preferable and will be sought in upcoming investigations (SBUF, 2013b).

Another outcome of this study showed that there are potential energy savings when it comes to for example heating of cabins, lightning, energy consuming tools and de-humidification of concrete constructions. Nevertheless, the reasonable amount of saved energy of these are unknown and as an attempt to get an answer, a model was developed with the purpose to present results of used energy visually (SBUF, 2013b). However, due to administration costs compared with energy costs and not enough usage by actors, the model was put on hold. To restart the model, it needs to be updated with the latest specifications on energy consuming products on the construction site[1].

A final outcome worth mention from one of the discussions concluded that the construction companies did not know how to systematically work with the energy efficiency during construction of buildings. A proposal was therefore made to provide companies with a handbook containing guidelines how to approach the subject. And with lack of knowledge or routines with energy efficiency, it was also considered of great importance that the companies would start to work with their energy knowledge continuously and have a well working routine for it (SBUF, 2013b). To illustrate their meaning of continuous work, see *Figure 2.1* illustrating the steps towards knowledge. The words above the steps stand for the learning process, the words beneath stand for the action process and the underlying green curve shows how the process grows with each step.

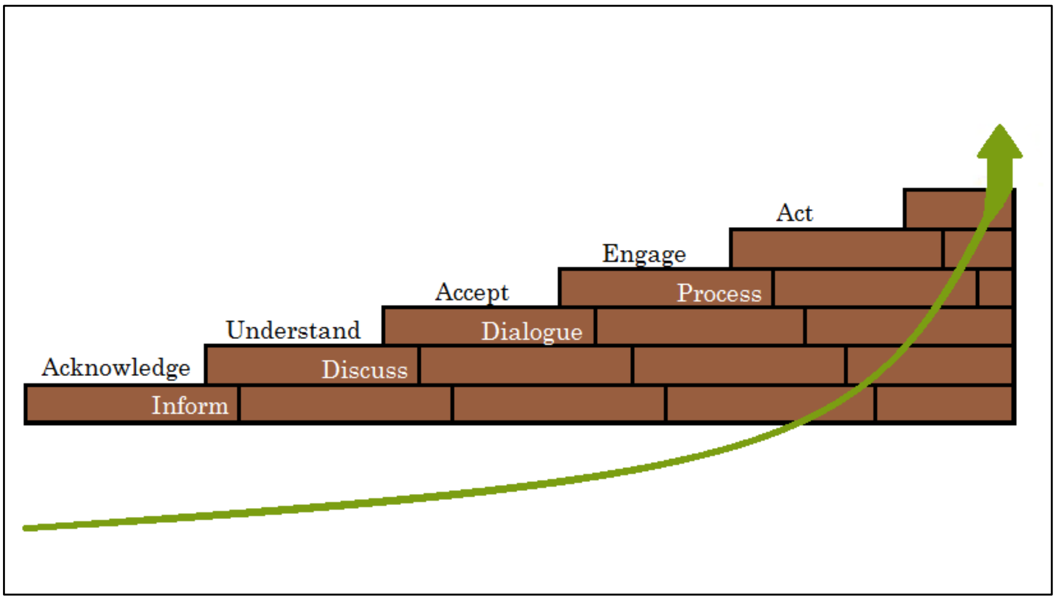


Figure 2.1 Illustration of the steps towards knowledge, according to SBUF.

[1] Norrman, Jonas; IMCG, consult for SBUF. 2016. Telephone call conversation. 17th of February.

2.3.2 Investigation made after the established energy audit law

A workshop arranged by Sveriges Byggindustrier (BI), the employers' organization for Sweden's construction industry, was held in September 2015 (n.d). Together with three of the construction companies in Sweden, Skanska, NCC and Peab, the workshop's focus was on how to approach the energy audit law along with companies' already existing energy efficient routines (Sveriges Byggindustrier, 2015).

When the requirement of achieving energy efficiency was established in 2007, all three participated companies from BI's workshop started with follow-ups of different kinds as to find routines how to work with energy efficiency. And now with a requirement of mapping each company's energy usage, the companies tried to figure out how to work with the law along with their existing energy efficiency routines. None of the three companies wants overwork and it was therefore important to discuss how to combine the routines with the law, especially when Energimyndigheten wants the results from each company's process reported (Sveriges Byggindustrier, 2015).

When it came to a discussion of possible ways to provide with valid values from construction sites, it was believed to be by the energy bills. However, since bills both can show fixed fees and consumed energy all together as a total amount, it creates uncertainties of the actual energy usage and its cost and might not provide with the energy data the energy audit law refers to. Moreover, it was considered that results of quantified data such as costs are more rewarded than qualitative data such as behaviour changes. Therefore, a greater challenge is to take decisions resulting in a qualitative change, even though it would lead to equally rewarding energy efficiency measurements as a quantitative change (Sveriges Byggindustrier, 2015).

So far the three companies have started to use certain measurements to fulfil the law, such as energy efficiency in a life-cycle-cost perspective, energy efficient cabins and energy-smart behaviour in some extent. Still Peab does not see this as sufficient to reach their own goals of energy efficiency and, therefore, wants help with developing a method to map their own energy usage at the company's construction sites (Sveriges Byggindustrier, 2015).

3 Peab

This thesis has been in cooperation with the company Peab and more specifically the business area Peab Construction. The company will therefore be introduced in this chapter before moving on to the main focus of Peab Construction. Thereafter will a brief overview of who has an influence on the company's construction projects before and during its construction, followed by a short presentation of the investigated construction projects.

3.1 The company Peab

Peab is a Swedish construction and civil engineering company, with offices located in Sweden, Norway and Finland. There are roughly 13 000 employees and has net sales of approximately SEK 43 billion (Peab, 2016a). They have four different business areas, which are construction, civil engineering, industry and project development, which *Figure 3.1* shows. The construction part performing contracts to both external and internal clients in the Nordic countries and comprises construction contracts, dwelling construction and building services (Peab, 2016b).

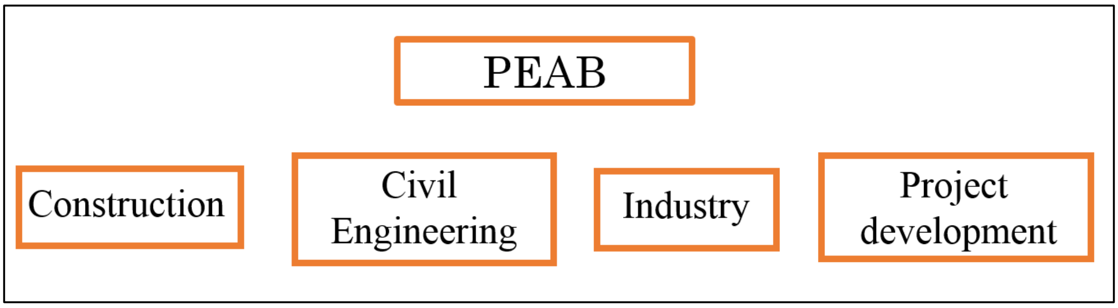


Figure 3.1 Peab's different business areas.

3.2 Peab Construction's projects

With the focus on the business area construction, an introduction to how their projects look like will here be presented in two steps. First who is working with a project before the construction phase and with what, followed by the whole management out on a project's construction site.

3.2.1 Project's process before construction

Before a construction project can start, the division of calculation makes an investigation of the costs of a project, which is the basis for the tender. When Peab got a project consented, the site manager makes a time-plan and construction calculation of costs that needs to be accepted by the construction manager. During the project, the costs will be followed up as to see that they do not exceed the budget.

3.2.2 At a construction site

The one responsible at the construction site is the site manager, whose primarily role is to assure that the time-plan and budget are followed. The site manager has supervisors responsible for different parts in the construction process and ensures that requirements are followed. There is also another role involved called KMA, which is a quality, environmental and working environmental coordinator that acts as a support for the construction management. The ones who actually builds the buildings are the constructions workers together with leased subcontractors, having a team supervisor as their representor.

3.3 Introduction to the studied projects

In this thesis, five apartment building projects has been studied, all of them located in Gothenburg and have the core material concrete. The first investigated project Landningsbanan has been studied thoroughly and four other projects has been studied briefly concerning their extent and energy consumption. The extent as well as the time of the year of construction is of interest when looking at the result of the projects' energy consumption. And before coming to such details, an introduction to the projects is presented here below.

3.3.1 The projects in Amhult

In Amhult, Gothenburg, three projects have been constructed at the same area with the designation B, A and C, where B was the first one to be constructed. The projects together can be seen as one big project that started in February 2013 and will be completed in June 2016. An overview of all the projects can be seen in *Figure 3.2*. The groundwork of the three projects was performed at the same time and they have a common courtyard and garage. Besides the groundwork, the three smaller projects were constructed one by one in the mentioned order B, A and C with some overlapping parts such as the garage and storages. In order to distinguish each of these projects, they will be shortly presented separately together with a figure showing which houses shown in *Figure 3.2* belongs to which project.

Figure 3.2 The figure shows the big project in Amhult (Mina bokningar, n.d).

Etapp 1 i Amhult is the first constructed stage B, comprising 71 rental apartments of one to four rooms, in two coherent houses, see *Figure 3.3*. The frame was constructed during spring and summer in the year of 2013.

Figure 3.3 Red frame shows the project B – Etapp 1 i Amhult (Mina bokningar, n.d).

Project Lufthamnen, stage A, is the second one to be constructed. This stage consists of three tenant houses, see *Figure 3.4*, with a total of 56 apartments with one to four rooms. The frame was constructed during winter and early spring in 2014.

Figure 3.4 Red frame shows the project A – Lufthamnen (Mina bokningar, n.d).

Project Landningsbanan is the last stage C in Amhult and is still ongoing. This one contains two buildings of six floors with total 60 apartments of one to three rooms, see *Figure 3.5*. The frame was constructed during winter and spring 2015.

Figure 3.5 Red frame shows the project C – Landningsbanan (Mina bokningar, n.d).

3.3.2 Project Elins gård

Elins gård is located in Högsbo, Gothenburg and was erected in August 2014 and completed in December 2015. It complies of four houses with five to nine floors and 117 apartments of one to four rooms, see *Figure 3.6*. The frames were constructed during autumn 2014.

Figure 3.6 The houses on the left side in the figure shows three out of four buildings in Elins Gård (Poseidon, n.d.).

3.3.3 Project Kajen

Kajen is located in west Eriksberg, Gothenburg at the coast and was built between December 2014 and January 2016. The project consists of two houses with ten floors each and a total of 87 apartments, see *Figure 3.7*. The frame was constructed during summer until winter time 2015.

Figure 3.7 The two houses visual in the middle of the figures shows the project Kajen's buildings (Peab Asfalt,, n.d.).

3.3.4 Overview of the projects

The table below, *Table 3.1*, presents a summary of the projects described above as to more clearly show the buildings' size differences. The table also shows what else is included in the project besides the buildings, such as a garage or storages.

Table 3.1 Summary of what is included in each of the projects with the extra information of number of floors for each building and if other complemented objects are built along with the project.

	Etapp 1 i Amhult	Lufthamnen	Landningsbanan	Elins Gård	Kajen
No. of buildings	2	3	2	4	2
No. of floors	5;5	5;5;5	6;6	5;6;7;9	10;10
No. of apartments	71	56	60	117	87
Other	-	Garage	Bicycle rooms	-	Garage

4 Approach of this project

Throughout this thesis, some words have been interpreted which is to be highlighted in the first section, followed by how and why the literature study has been used. Then the two following sections presents the gone through approaches until the final concept was achieved, and lastly the performed survey will be presented.

4.1 To overcome communication issues

It was noted throughout this thesis that a word could be used in different contexts from time to time which created confusion. Therefore, it felt necessary having a clarification of how words are used in this thesis, see section Notations in the beginning of this thesis.

4.2 Literature study

This thesis started with a literature study of the energy audit law's background, followed by previous investigations within the field of how to map energy within the construction industry. Since energy mapping is a quite new area, there were not much to work with, meaning there were no rights or wrong when choosing an approach. Therefore, the study aimed to find possible approaches to use in this thesis. And with the purpose to find a concept that will fulfil the energy audit law, it was decided to focus on the investigations carried out in Sweden.

After been reading about energy efficiency investigations concerning the house construction industry, two of the found investigations were chosen to be useful in this thesis. Both of them presented information about how the industry have been discussing energy efficiency, where one of them was an investigation before the established law and the other afterwards. This literature is presented in the previous chapter together with background information about the energy audit law, to both fulfil a part of the thesis's purpose and enlighten the subject to the reader.

From one of the investigations, an attempt of an Excel model with energy usage data was described and became of great interest. However, when got in contact with Jonas Norrman, who worked with the model, it was acknowledged the model no longer was in use. This due to too much of updated data and administration was required to maintain the model. With that in mind it was a desire to create a functional model, based on a well-known structure within Peab Construction as an attempt to avoid an excessive administrative model. And for that reason, the final literature study focused on documents provided by the company and how they previously have collect data. How and when these documents were used will be presented in the following sections at the time when they actually were being used.

4.3 The first concept: In accordance with the law

In order to create a general model suitable for the house construction site, there is a need of a method providing how and where to collect data fulfilling the law's requirements. As mentioned in previous section, there is not yet such a method explaining how it should be done. The next phase after the literature study was therefore to find a method, followed by a model which sorted the data.

4.3.1 Where to collect data

To come up with a method of how to collect data for energy mapping, there was a need of a construction project used as a *case study* to make the investigations. It was decided to only choose one project to get a first frame, otherwise it would be too time consuming to both learn and visit more projects.

The chosen case study needed to be in the area of Gothenburg and be quite far in its construction phase in order to easily make site visits and collect data. These requirements were fulfilled by the project Landningsbanan in Gothenburg. The project will be finished in June 2016, and when this thesis started it had just begun with its interior work, meaning the project were in a good time period to contribute with both data and facts. There were several workers on the site which gave the additional possibility to have interviews to get knowledge of the performed construction activities.

If a case study on a project in an early phase had been used instead, the possibility to gain specific data through measurements of for instance the cabins energy consumption could have been an option. However, the timeframe limited this possibility and instead it was seen as more beneficial with an already ongoing project and discover whether there were any left out data and/or measurements.

When it comes to limitations within the thesis's collected data, it was decided to limit the study within the site visit's fence and neglect the transportations to and from the site. This since that kind of energy is not energy Peab Construction's has any impact on. The same goes for the energy paid by the leased entrepreneurs. To illustrate this limit of the site and the considered energy, see *Figure 4.1*. The neglected transportations are illustrated by the arrows to and from the site and are neglected due to the made limitation of only see the energy within the fence. Everything within the red dashed circle is illustrating the construction site, where all grey figures, are neglected energy consumers whilst the green ones are included energy consumers in the energy mapping.

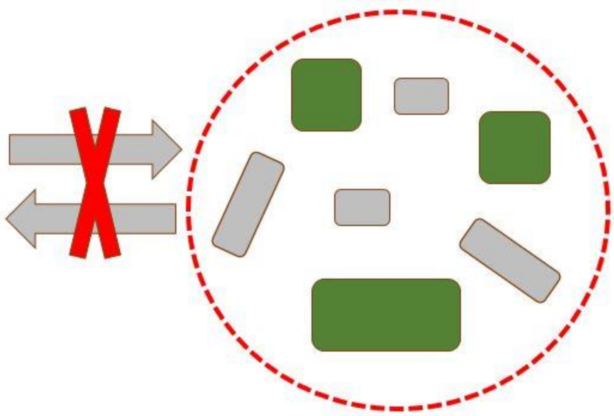


Figure 4.1 The limited area of the site along with the green parts representing the considered energy consumption at the site, whilst the grey parts is neglected energy. The arrows represent the transportation coming and going from the site and are neglected as well.

4.3.2 First draft of the method

The process before the method was found can be described as an iterative process since the approaches were refined over and over until the first draft method was achieved. During this process, material provided by Peab were used, several visits to the project Landningsbanan were made and later on the outcome was discussed with tutors for perspective. This process will be presented in the next subsections.

4.3.2.1 The search after a table to sort out collected data

The first attempt was to sort out and collect energy data by finding a relation between consumed energy and the construction process's activities. A table called the *Construction part table* was introduced in the beginning of this thesis by Peab. The table is illustrated in *Figure 4.2* as to just show the table's design and is more visually and readable in *Appendix A*. The meaning of the table is to get an overview of the activities performed at a construction site and the *Construction part table* was the start of the inspiration to a similar table. The developed table had instead the aim to suit the purpose of mapping energy consumed in different parts of the construction process by categorize each activity. This new developed table was then called the *Energy part table*, see *Appendix B.*

0	SAMMANSATTA BYGGDELAR	00 Samman-satta	01 Demon-tering	02 Rivn. av Inr/Utr	03 Rivn. av vägg/bjkl	04 Rivn. övrigt	05 Rivn. för hiss/trp	06 Håltagn Förstärkn.	07	08 Provi-sorier	09
1	MARK	10 Samman-satta	11 Röjning Rivning Flyttning	12 Schakt Fyllning	13 Mark-förstärkn. Dränering	14	15 Ledning Kulvert Tunnlar	16 Vägar Planer	17 Trädgård	18 Mark-utrustn. Stödmur	19
2	HUSUNDERBYGGNAD	20 Samman-satta	21	22 Schakt Fyllning	23 Mark-förstärkn. Dränering	24 Grund-konstr.	25 Kulvert Tunnlar	26	27 Platta på mark	28 Huskompl	29
3	STOMME	30 Samman-satta	31 Väggar	32 Pelare	33 (Prefab)	34 Bjälklag Balkar	35 (Smide)	36 Trappor Hiss-schakt	37 Samverk Tak-stomme	38 Huskompl	39
4	YTTERTAK	40 Samman-satta	41 Tak-stomme	42 Taklags-kompl	43 Tak-täckning	44 Takfot & Gavlar	45 Öppnings-kompl. Takluckor	46	47 Terasser Altaner	48 Huskompl	49 (Plåt)
5	FASADER	50 Samman-satta	51 Stomkomp Utfackning	52	53 Fasad-beklädnad Ytskikt	54	55 Fönster Dörrar Partier	56 (Utvändiga trappor)	57	58 Huskompl	59
6	STOMKOMPLETTERING	60 Samman-satta	61 (Insida yttervägg)	62 Undergolv	63 Inner-väggar	64 Innertak	65 Inv dörrar & Partier	66 Invändiga trappor	67	68 Huskompl	69
7	INV. YTSKIKT	70 Samman-satta	71	72 Ytskikt golv & trappor	73 Ytskikt vägg	74 Ytskikt tak Undertak	75 (Målning)	76 Vita varor	77 Skåp & Inredn. snickerier	78 Rums-kompl Övrigt	79
8	INSTALLATIONER	80 Samman-satta	81	82 Process	83 (Storkök)	84 Sanitet Värme	85 Kyla Luft	86 El	87 Transport	88 Styr	89
9	GEMENSAMMA ARBETEN	90 Samman-satta	91 Gemens. arbeten	92	93	94	95	96	97	98	99

Figure 4.2 The Construction part table.

The *Energy part table* was meant to be filled in by help from the site manager, sorting out the amount of used energy within each activity. But since it was too hard to comprehend and not possible to distinguish used energy of each construction activity, it was not possible to fill in such desired data. Therefore, a new approach of how to sort and collect data was created.

Since the *Energy part table* was too comprehensive, the thought was to create a new table that was more graspable and in more detail. By breaking down the *Energy part table* into each of the construction project's activities from the time-plan, each activity could then include energy consuming categories.

The first activity shown in Landningsbanan's time-plan was the erection of the frame, since the ground work was already performed during the previous projects in Amhult as described in *3.3.1 The projects in Amhult*. Therefore, the frame was the first construction activity to be investigated in a new divided table with energy consuming categories such as hand machines, construction crane, lights, cabins, containers, and heating of concrete. This new table was called the *Frame part table*, see *Figure 4.3* which aims to just show the resemblance between this table with the *Construction part table* in *Figure 4.2*. If a clearer and readable view is preferred, the table is found in *Appendix C*.

FYLL I HUR MYCKET DEN DRAR OCH HUR MÅNGA TIMMAR DEN ANVÄNDS   DETTA ÄR PER PLAN   STOMME - ifylld av Lagbasen Fredrik   10Feb

MOMENT/MASKIN	SLAGBORR	MUTTERKNACK	SKRUVDRAGARE	PAPEGOJA	ROT. LASER	BYGGKRAN	UTTORKNING
FÖRBEREDELSE SKALVÄGGAR (1d)	4 tim	2 tim			2 tim	30 min	
MONTAGE SKALVÄGGAR (1d)		2 tim		5 min		4 tim	
TÄTNING SKALVÄGGAR (~~1d~~) (1/2d)	2 tim	1 tim					
MONTAGE UTFACKNINSVÄGGAR (2d)	4 tim	1 tim	1			8 tim	
MONTAGE VILPLAN + TRAPPA (1d)	30 min	5 min				1 tim	
RIVNING AV STÄMP (24d)							

Figure 4.3 Illustration of the Frame part table, meant to clearly enough show the resemblance between this table and the Construction part table.

With help of the work preparations' lists, all used hand machines were found and by noting every energy consuming part used at the site, it became more graspable exactly what was investigated. This was necessary when discussed the frame activity and used energy consuming objects with the construction site's workers. However, since no one at the site did know exactly how much energy the cabins or machines had consumed during the activity, the energy consumption of each subcategory from the *Frame part table* was estimated. This was done with help by workers' estimation of their working hours [h] for each and every category and then the energy effect [W] of each one of them was given by the dimension effect. All the given data were collected and sorted into the *Frame part table* and afterwards were the consumed energy [kWh] calculated. Having found a way to sort the collected data, the next step was to verify whether this table and approach was valid or not.

4.3.2.2 Verification of table and used approach

To be able to verify if the calculations from the *Frame part table* were correct or not, they were compared to the energy consumption given from bills. If the total amount from the calculations agrees with the amount presented from the bills, then a way of mapping the energy consumption for each category would have been found, see illustration in *Figure 4.4* presenting the idea of the verification.

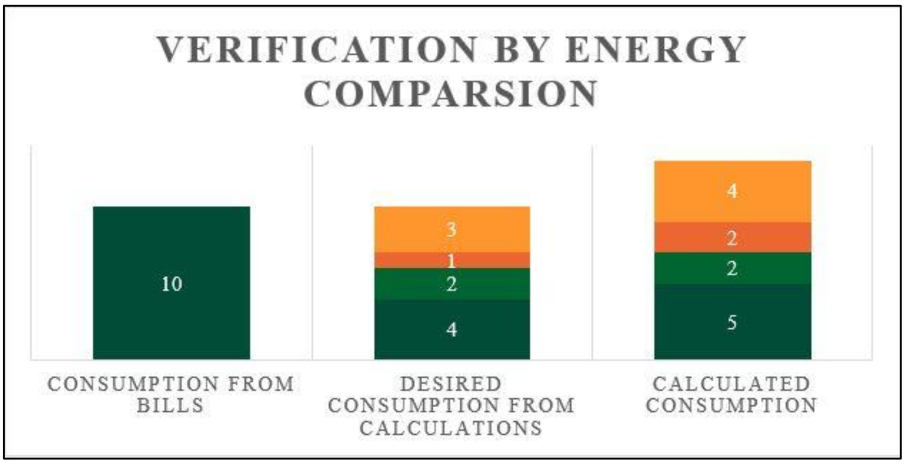


Figure 4.4 Illustration of the idea with the verification by comparing the bills with calculations.

However, the calculations from the investigation did not match the monthly bill values at all, see *Figure 4.4*. This raised the questions *why did it not work* and *even if it did work, does it provide with desired information*? To answer the first question, it did not work because of two reasons. First of all, the calculations were based on the workers' memory of their work one year ago and secondly, the used effect values in the calculations were the dimensioning values and not the actual valid values. This leads to the other question, whether the approach provided with desired information. Since this thesis strives to be in accordance with the energy mapping law, it means the approach do not satisfy the law's requirements as it is based on mostly estimated values and not valid ones.

Besides, when reflected on how time consuming and the workload this approach required, then it did not even seem as a good approach to recommend to Peab Construction. So even if the approach would have worked, the result itself would not have been providing with good enough data or graspable result when looking so closely at the energy consuming categories. Instead a new approach was needed, and based on the previous approaches, two requirements of the new one were made. First of all, the collected data needs to be valid and secondly the level of activity or categories connected to the data had to be quite general.

From the previous approach, valid facts of used energy were gained from energy bills which includes electricity, gas and district heating. Then the new approach needed to set the energy data in relation to activities, and after discussion with the site manager the most general match was the construction process's time-plan. By using the time-plan, it provided with the desired overview and if there were any questions raised concerning an activity, then there was the possibility to go into detail within that specific activity by look more closely into the time-plan or ask the site manager.

This means a valid method of how to collect data from the construction site were through the energy bills and the time-plan. The next step was to sort the data together based on the found method, and this was tried by using a model in Excel, a program available for everyone working at Peab.

4.3.3 The first draft of the model

The collected energy consumption data from bills were compiled in an Excel table, showing each month's energy consumption of each energy carrier; electricity, district heating and fuel. To make the results more visual, the table was linked to a diagram where each energy carrier was distinguished by using different colors. This way of map and present the energy felt suitable and possible to adapt to other projects and therefore became the first draft of the energy mapping model. The first created bar diagram is seen in *Figure 4.5* and illustrates the total amount used energy for each month by showing electricity with a green color along with the district heating with an orange color. At the time when the diagram was created, the fuel had not been looked through. Note as well that no values of consumed energy [kWh] is presented, which is the idea throughout this report since the purpose is to find a method and a general model to map consumed energy.

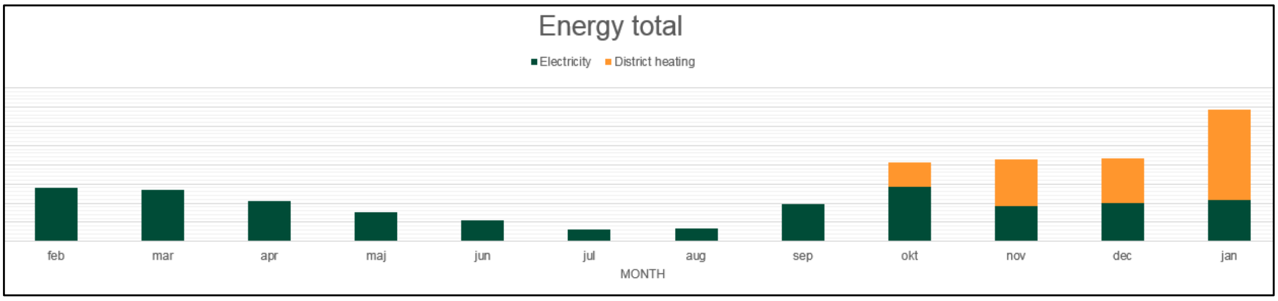


Figure 4.5 – The first created bar diagram, were the green colour represent electricity and the yellow district heating.

The next step with the model was then to relate the construction activity performed during each month in order to find possible connections between energy usage and the activities.

With this first draft of the concept with accordance with the energy audit law, it was presented and discussed with people from Peab. And with their approval both from the presentation and from written feedback in a questionnaire, see *Appendix D*, the next phase in this thesis was to develop and improve the concept.

4.4 Development of the concept: Understanding energy consumption

This section will present how the concept was developed until the final method and model were achieved.

4.4.1 Developing the method

Providing an alternative energy performance indicator

Another idea was that the model would generate energy performance indicators once a project was finished. The chosen indicators then needed to be seen as useful for Peab and when asked what sort of energy performance indicator they used, they mentioned a couple where [kWh/m^2] and [kWh/SEK] were two of them. However, these indicators do not indicate any relation to the constructed building's energy consumption during its service life. It was therefore believed that the buildings somehow need to be taken under consideration when discussing the energy consumption at a construction site. And with that, an alternative indicator was developed and will be referred as the measuring value.

If energy consumption from several projects are collected by using the proposed method, with the total energy consumption presented in the model, then an average value of how much energy is used during a project can be estimated both by a total amount [kWh] and with indicators. These indicators can be the ones mentioned by Peab above which consider the actual energy consumption from the construction period. And together with the extra indicator, the measuring value which considers the constructed building's energy usage during its service life, more useful energy efficiency measurements might be possible to find.

Nevertheless, no matter of how this measuring value will look like, it must somehow be calculated based on the collected data. And since no collected data presented values concerning the studied project's buildings' energy usage, the project Landningsbanan was visited once more. During this visit, documents containing energy calculations of the buildings' energy usage throughout their service lives were collected. By the provided data from the energy calculations, the idea became to compare the consumed energy by Peab Construction with the buildings' total energy consumption and this relation would be the measuring value. More of this measuring value will be presented in *5. Result*.

By collect even more data with the purpose of include the measuring value within the model, the method was developed to include the project's energy calculations as well.

Hourly energy usage

The project Landningsbanan's electricity supplier was contacted during the spring, this in order to get data about hourly electricity usage for a couple of weeks during both the winter and summer season in 2015. With this information, data tables were transformed into diagrams in Excel, showing hourly changes during a full week. By study the diagrams, energy usage variation throughout the days along with the activities during the given weeks from the time-plan could be seen in more detail than it currently did in the model. The thought of this, except to see whether the hourly energy usage was necessary or not, was also to see how much of the total electricity were used during working hours and non-working hours. The Landningsbanan's site logbook of the ones working overtime was therefore looked through in order to see how much of the electricity usage were due to workers working overtime. This was of interest since if there were a greater energy consumption during non-working hours without anyone working at the site, then it would mean there were some sort of energy consuming devices kept on at all times for some reason. And the investigation could continue with finding these reasons.

The outcome of this approach will be given in the chapter *5. Result*, as it gave further understanding of the project's energy consumption. However, the approach will not be included as a part of the method since it did not include data effecting the final model. And when looking for a general model providing an overview, this approach was also seen as too detailed.

Previous attempts to map a construction site's energy within Peab
There has been complementary data from other projects during this thesis by contacts with site managers, this to understand previous attempts in energy mapping within Peab Construction. From previous projects, clients have been asking for energy consumption in different ways, where in one project it was asked for a list with everything that consuming energy at the project's construction site. But when the client did not know what to do with that list, the attempt was soon dropped. And since the approach did not provide with any useful information, this approach was therefore neglected.

Another project's site manager was asked to present the energy consumption and did so by show monthly energy usage in a diagram. When showing the diagram, the monthly energy consumptions were explained by having the project's time-plan available. Since the task was asked by the project's client, the result was not thought of to be used in any other way. This approach was more similar to this thesis's final method, and when asked the site manager of the time effort behind presented result, it seemed reasonable. Of that reason, the found method seemed to be reasonable as well.

4.4.2 Development of the model's parameters

The model in Excel were developed further by adding other parameters into the model. This has been done to provide with more useful result and these added parameters will be presented in this section.

Temperature
During the winter season, heating devices were used at Landningsbanan and during this period the energy consumption were higher. The outdoor temperature was therefore seen as interesting parameter to add into the model. After a search online for daily average temperatures to use, a webpage with collected climate data from several weather stations in Sweden was found. This webpage is called RL, and provided an average value of each day over the last 15 years.

When it came to which climate data to recommend using within the model, another climate webpage, SMHI, was also seen as an option. This due to the temperature values from this one were based on several years of average data, whilst the webpage RL gives the specific daily average temperature throughout each year. The decision was therefore to let the one who is going to use the model to decide which one to use.

Cabin and other measurements
The energy used in the cabins were a parameter that would have been interesting to know, since they were mentioned both in literature and by Peab as a huge energy consumer. However, since no measurements were taken on the site's cabins in the project Landningsbanan, the consumption was instead estimated by calculations provided from Peab.

Further information concerning the cabins were gained by being in contact with the company Lambertsson, which are the ones delivering cabins to Peab's projects. By the given information from Lambertsson of the different kinds of cabins, calculations were adjusted to be suitable for each one of them. However, since these calculations only were used to provide with an estimation of how much energy the cabins were consuming, they cannot be used as a valid value for the energy mapping. Therefore, the possibility of adding cabin or other measurements data within the model was created in hope to encourage upcoming projects which will use this model to provide with valid data from measurements.

Fuel
From the project Landningsbanan, the only type of fuel used by Peab Construction was gas. Since it was told by Peab that other types of fuel could be used in projects, extra columns were added where the type of used fuel can manually be filled in. When it comes to the unit of the consumed fuel, it was not given in [kWh] and therefore two webpages for this unit transition was added in the model, Fogas and Biogasportalen.

Extra parameters of interest
When discussed the energy consumption with the site manager of Landningsbanan, it was said the amount of consumed energy was more interesting if it was set in relation to the economics. The aspect of the economics was not from the beginning a part of the thesis's main focus, still this aspect showed the necessity to be included. Therefore, a column where the costs can be filled in for each energy carrier was added in the model, where the total cost also will be presented at the end of a project.

Other parameters of interest for Peab were also added, as the ones mentioned in previous section *4.4.1 Developing the method* about useful energy performance indicators such as [kWh/m^2] and the suggested indicator, the measuring value [%]. More about these indicators will be presented in *5. Result.*

4.4.3 Verification of the model with help by other projects

To see whether the model only was suitable for the studied project or others as well, the model was tested on other house construction projects. This was done by collecting data from bills, time-plans and energy calculations, and then studying the outcome of each of the projects in the model. In total four different projects were studied in the model. One of these are the three smaller projects in Amhult introduced in *3.3.1 The projects in Amhult* seen as only one project, and the reason for doing so along with why only four projects in total were studied will be explained in this section.

The first projects tested were the two other phases compketed before Landningsbanan in Amhult. This due to the projects' time-plans overlapped and it was easier to see them as one instead of separately. Since the studied project now had a longer timeframe comparing with Landningsbanan's, the model was easily adapted to this by only expand the timeline.

The next projects to be tested in the model were Elins Gård and Kajen. The difference in energy consumption compared to the first projects was for example how and when they have used district heating. This pointed out the question *why do they differ from each other?* The question was discussed with people involved in the projects in order to learn more about other possible causes for discrepancies than what the collected data could provide. After the discussion and having compared the different ways the projects have been carried out, the way the projects had been constructed showed to have a great impact on the energy consumption. And moreover, it was found out that another great impact was when the constructed buildings were considered to be airtight since that affected the energy usage at the construction site. Therefore, the date of airtight house was added in the model.

After have studied all the projects, the model was seen as general enough since all the projects' collected data are based on the method of information which are found in every construction project.

4.4.4 Final development of the model

Another developed measure in the model was the possibility to predict the energy consumption for a construction project. Then the model is to be used before the construction has even started, which was seen as a possibility after investigated in how a project's process looks like before the actual construction period, see more of this in *3.2.1 Project's process before construction*. And after a discussion with Peab, it was believed that by using this measure and compare the predicted energy values with the actual energy usage from the site, the division of calculation's and site managers' ability to predict energy consumption might be advanced.

The final thing to do with the model was to make it both easier to use and more appealing for the ones going to use it. This was done by feedback from the Landningsbanan's site manager and others from Peab, which might be the potential users.

4.4.5 Where to implement the model

So far the focus has been on finding a method and develop a model, but exactly where the model should be implemented was not yet clear. Approaches leading to where model could be implemented began with a discussion with the Landningsbanan's site manager. From the discussions it was told how a project needs to follow certain sustainable requirements presented within an Excel file. After looked through these requirements, this document was seen as a potential file the model could be implemented into.

Then it was also discussed with the site manager how the model could be connected with other programs used within Peab, such as the billing system, where the system was showed and explained. However, such an implementation was considered as a development of the model's accessibility in Peab and first of all the model is believed to be manually tested before further development.

There have been other brief discussions and meetings with the purpose to find potential programs to connect to the model. However, when not having the time and main focus on finding how the model should be implemented into other programs, it was decided to not proceed any further with this question.

4.5 Survey of the view of energy on site

While visiting the site of Landningsbanan, the experience was that the question of energy consumption was not very highlighted. Since the model does not consider the workers' behaviour, it was of interest to see if there were something that could be added in the model or thought of when presenting the model concerning the way workers perform the construction activities.

To investigate the workers general view of energy a questionnaire was handed out. The questions were based on activities and categories seen as energy consuming and possible sources of the energy consumption at the site. The questionnaire's design can be seen in *Appendix E*.

The participants were asked in one of the questions to choose five categories from a given list of different energy consuming categories at the site, and to rank them first with the highest energy consumer and then the next highest and so on. This ranking system appeared not to have been understood by all the participants, which instead led to some unranked answers.

In total nine people participated; three from the Peab Construction site office, three of the Peab Construction's workers and three subcontractors. Since not many workers participated, the result could not be seen as a general result. However, the result of the survey was still helpful since the purpose was to get an overview of workers' thoughts regarding potential efforts on the construction site in order to decrease unnecessary energy usage.

5 Result

The resulted model ENKLA and its function and outlook will be presented in this chapter. Along with the model, results from the investigated projects will be presented and furthermore the results from the survey and noticed behaviour at Landningsbanan.

5.1 The model ENKLA

The proposed model concerning energy mapping has mainly been built up based on the project's used method of collecting data. The method was developed by for instance looking into the construction project’s time-plan, energy related bills and energy calculations made by consultants. Through the method, data was sorted out to develop the model in an Excel file, see *Appendix F*, and has been given the name ENKLA, where the name is a Swedish acronym for *energy mapping analysis*. The model ENKLA will be presented in the following section with illustrating figures as to provide with an overview. For a closer look, see *Appendix F*.

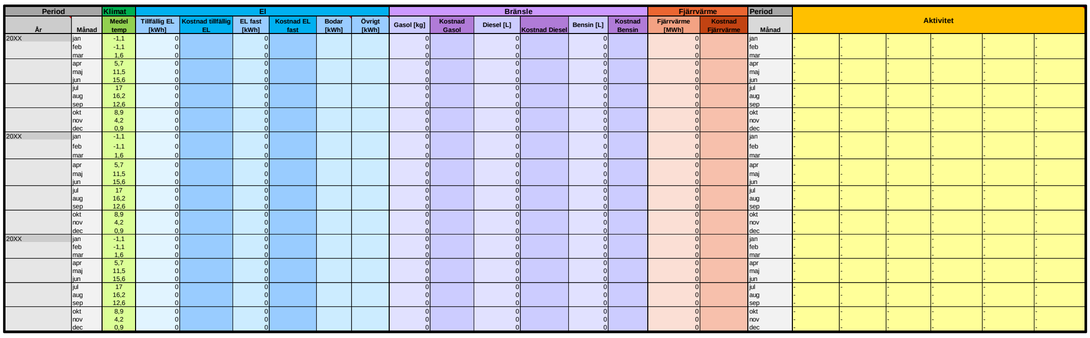
5.1.1 Input information

The first sheet in the Excel file is where the user will manually type in data and measurements about the project and the collected energy data for each month. The outlook of the table with information of the building is seen in *Figure 5.1*, where the needed information about the building is for example the size, geographically location and frame material. The building information is used in order to localize a connection between it and for example the geographical location’s impact on the energy consumption. Later on will the input data be used to calculate a measuring value, meant to make it possible to compare a project’s energy consumption with other projects’ in the same geographical area. The measuring value will be explained further in section *5.1.3 The measuring value*.

Information om Byggnad							
Namn på projekt	Solhuset	**Stommaterial**	Betong	Ex. Betong, trä	**BTV**	0	m^3
Ort	Göteborg				**BoA**	0	m^2
					BTA	0	m^2
Hyresrätter		**Datum för tätt hus**			**Atemp**	0	m^2
Bostadsrätter							
Antal hus		**Energiberäkning färdig byggnad**		I kWh/kvm BoA, år - uppskattat värde	**Garage**	X	
Antal lägenheter							
Antal våningar		**Livslängd**	50	år			

Figure 5.1 Table illustrating the needed input of the building.

The other table where data of energy is needed can be seen in *Figure 5.2*. The chosen colours are to make the table easier to overlook and appealing. A closer look of the table is seen in *Appendix F* and note that the input values in this figure below, which also is the same one in *Appendix F*, is not connected to any real project. Besides input of the energy consumption, there is also the possibility to type in the energy cost is of interest.



Period		Klimat	El						Bränsle						Fjärrvärme		Period	Aktivitet					
År	Månad	Medel temp	Tillfällig EL [kWh]	Kostnad tillfällig EL	EL fast [kWh]	Kostnad EL fast	Bodar [kWh]	Övrigt [kWh]	Gasol [kg]	Kostnad Gasol	Diesel [L]	Kostnad Diesel	Bensin [L]	Kostnad Bensin	Fjärrvärme [MWh]	Kostnad Fjärrvärme	Månad						
20XX	jan	-1,1	0		0				0		0		0		0		jan	-	-	-	-	-	-
	feb	-1,1	0		0				0		0		0		0		feb	-	-	-	-	-	-
	mar	1,6	0		0				0		0		0		0		mar	-	-	-	-	-	-
	apr	5,7	0		0				0		0		0		0		apr	-	-	-	-	-	-
	maj	11,5	0		0				0		0		0		0		maj	-	-	-	-	-	-
	jun	15,6	0		0				0		0		0		0		jun	-	-	-	-	-	-
	jul	17	0		0				0		0		0		0		jul	-	-	-	-	-	-
	aug	16,2	0		0				0		0		0		0		aug	-	-	-	-	-	-
	sep	12,6	0		0				0		0		0		0		sep	-	-	-	-	-	-
	okt	8,9	0		0				0		0		0		0		okt	-	-	-	-	-	-
	nov	4,2	0		0				0		0		0		0		nov	-	-	-	-	-	-
	dec	0,9	0		0				0		0		0		0		dec	-	-	-	-	-	-
20XX	jan	-1,1	0		0				0		0		0		0		jan	-	-	-	-	-	-
	feb	-1,1	0		0				0		0		0		0		feb	-	-	-	-	-	-
	mar	1,6	0		0				0		0		0		0		mar	-	-	-	-	-	-
	apr	5,7	0		0				0		0		0		0		apr	-	-	-	-	-	-
	maj	11,5	0		0				0		0		0		0		maj	-	-	-	-	-	-
	jun	15,6	0		0				0		0		0		0		jun	-	-	-	-	-	-
	jul	17	0		0				0		0		0		0		jul	-	-	-	-	-	-
	aug	16,2	0		0				0		0		0		0		aug	-	-	-	-	-	-
	sep	12,6	0		0				0		0		0		0		sep	-	-	-	-	-	-
	okt	8,9	0		0				0		0		0		0		okt	-	-	-	-	-	-
	nov	4,2	0		0				0		0		0		0		nov	-	-	-	-	-	-
	dec	0,9	0		0				0		0		0		0		dec	-	-	-	-	-	-
20XX	jan	-1,1	0		0				0		0		0		0		jan	-	-	-	-	-	-
	feb	-1,1	0		0				0		0		0		0		feb	-	-	-	-	-	-
	mar	1,6	0		0				0		0		0		0		mar	-	-	-	-	-	-
	apr	5,7	0		0				0		0		0		0		apr	-	-	-	-	-	-
	maj	11,5	0		0				0		0		0		0		maj	-	-	-	-	-	-
	jun	15,6	0		0				0		0		0		0		jun	-	-	-	-	-	-
	jul	17	0		0				0		0		0		0		jul	-	-	-	-	-	-
	aug	16,2	0		0				0		0		0		0		aug	-	-	-	-	-	-
	sep	12,6	0		0				0		0		0		0		sep	-	-	-	-	-	-
	okt	8,9	0		0				0		0		0		0		okt	-	-	-	-	-	-
	nov	4,2	0		0				0		0		0		0		nov	-	-	-	-	-	-
	dec	0,9	0		0				0		0		0		0		dec	-	-	-	-	-	-

Figur 5.2 Table of input energy data and its cost.

Furthermore, the project's monthly energy usage is filled in the first part of the table where the energy carrier electricity, fuel and district heating is distinguished. These monthly values are connected to the same month's activity on the site, which is filled in into the right columns. An extra column in the table is spared if there is a category missing from the model. The cabins energy consumption can be filled in if it is measured, and if it is not, then there is a separate sheet were it can be estimated. However, estimated values cannot be used as a valid value in the energy mapping due to the energy audit law, instead it should be viewed as an interest for Peab to have an approximated number of the cabins' energy consumption.

In addition, there is a table where predicted energy values can be filled in, located at the next sheet. The table makes it possible to predict and get a hint of the energy consumption and energy costs within a project before it has started. During and after a project construction the actual energy consumption can be compared to the predicted one to see whether they match or not. This can be useful for both the site manager and for the people working with calculations costs of projects to have control over the energy consumption and its costs throughout a project's construction period.

The last two worksheets in the Excel file consists of information and instructions of how to use the file and lastly there is a reference list attached with the used websites for temperature and fuel values.

Finally, ENKLA will with the input information provide with energy results, which will be described in the next section, *5.1.2 The outcome*.

5.1.2 The outcome

The monthly energy data typed in the input sheet's input table is linked to the result tables and diagrams, where the result of the project's total energy consumption will be presented once the project is finished. The result table, see *Figure 5.3*, shows the consumed energy both in total [kWh] and in units such as [kWh/m_{BOA}^2] and [kWh/m_{BTA}^2] depending on Peab's interest and what the result will be used for. The units have been chosen depending on the interest of the people working with calculations and of the project management in Peab.

PERIOD		KLIMAT	EL				BRÄNSLE		FJÄRRVÄRME		ENERGI						
År	Månad	Medel temp	EL bodar [kWh]	EL övrigt [kWh]	EL tot [kWh]	Kostnad EL	Bränsle tot [kWh]	Kostnad Bränsle	Fjärrvärme [kWh]	Kostnad Fjärrvärme	Energi tot [kWh]	Energi tot/BoA [kWh]	Energi tot/BTA [kWh]	Energi tot/Ight [kWh]	Energi tot Atemp [kWh]	Energi tot/BTV [kWh]	Totalkostnad energi
20XX	jan	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
20XX	jan	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
20XX	jan	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	Totaler:		0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0	0,0	0,0

Mätvärde baserat på energiberäkning i färdig byggnad	
0%	av den totala energi förbrukningen (under produktion och under byggnadens livlängd) går åt i produktionen.

Figure 5.3 The result table.

Each of the two sheets in ENKLA contains a bar diagram. The first diagram shows the total amount consumed energy for each month in a bar, see *Figure 5.4*. The bar is split into the energy carrier electricity, district heating and fuel along with measurements of cabins and other, if any have been taken, which are distinguished by having given them different colours. In this diagram a temperature curve is also added to see what the climate was at the time the energy usage occurred. The result from this diagrams is mainly meant to provide an overview of the energy usage due to the construction activities which is of interest for the energy audit law. The result can also be used to create statistic values of the energy usage at Peab's construction sites when seeking possible energy efficiencies.

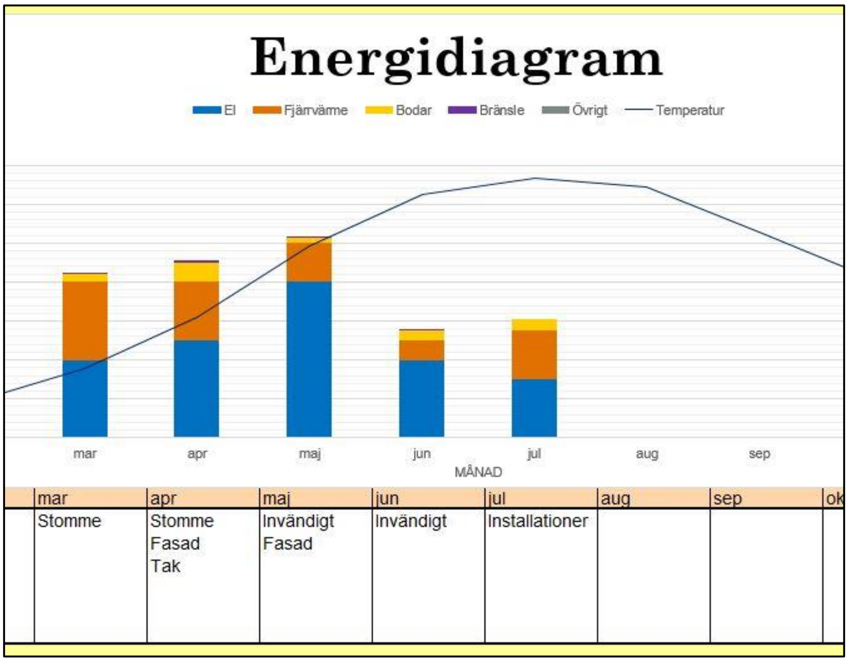


Figure 5.4 Bar diagram presenting the monthly energy consumption divided into electricity, district heating, cabins, fuel and other. Blue colour is the electricity, orange district heating, yellow cabins' estimated energy consumption and the purple the fuel. The dark blue curve is the temperature variation.

The other bar diagram in the following sheet is instead presenting the total amount of consumed energy compared with the predicted amount energy along with a temperature cure, see *Figure 5.5*. The consumed energy is meant to be decided along with the time-plan and construction calculation mentioned in section *3.2.1 Project's process before construction*. This energy prognosis can be written in a table with the same structure as the result table shown in *Figure 5.3*, see *Appendix F* presenting this prognosis table. By doing so, the knowledge of the believed energy consumption in a project will be improved by put some more thoughts into it in beforehand. Once start processing how correct the assumption was during the construction period and see the cost possible gains with it, there energy consumption will be more thought of automatically.

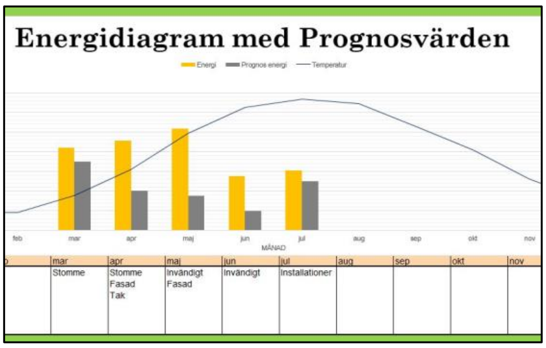


Figure 5.5 Bar diagram showing the monthly energy consumption (yellow bar) compared with the predicted energy consumption (grey bar). The dark blue curve is the temperature variation.

5.1.3 The measuring value

Besides the amount of energy consumption, a measuring value was created. The value is a way of comparing projects construction's energy consumption depending on the constructed buildings' characteristics. The characteristics makes an effect of how much energy it will consume during its service life. Characteristics that effects the energy usage are for example the geographical location, the size of the buildings, [m^2] and [m^3], its service life and if it is designed to be a passive house or of other kind. Thereof the proposed measuring value.

To avoid long sentences some shortens will here be used:
$E_{construction}$: Peab construction's energy consumption in [kWh].
$E_{service\ life}$: The Buildings energy consumption throughout its service life in [kWh].

The measuring value can be calculated in two different ways, both in percentage. The first is to compare $E_{construction}$ with $E_{service\ life}$, see *eq. 1*, which means a indicator of used energy from the buildings construction period with the buildings energy throughout its service life. Therefore was this measuring value given the name $EM_{compare}$ [%].

An alternative way is to compare $E_{construction}$'s share of the total summation of consumed energy $E_{service\ life}$ and $E_{construction}$, see *eq. 2*. This measuring value was given the name EM_{share} [%].

$$EM_{compare} = \frac{E_{construction}}{E_{service\ life}} * 100 \qquad (eq.\ 1)$$

$$EM_{share} = \frac{E_{construction}}{E_{construction} + E_{service\ life}} * 100 \qquad (eq.\ 2)$$

5.2 Result of projects gained by the method

The result presented in this section will be what was gained by using the proposed method applied on each project. Data about the projects has been collected and investigated through the model. The first studied project, project Landningsbanan, is more deeply investigated and will therefore have the most presented results.

Note that no values of consumed energy [kWh] is presented, since the purpose is to find a method and a general model to map consumed energy.

5.2.1 Project Landningsbanan

The ground construction of Landningsbanan is not considered in this result since it was made in conjunction with the earlier projects in Amhult. Instead the first activity in Landningsbanan's time-plan was the frame, made of concrete, and was constructed during the spring 2015. Note that this project was not finished when this thesis still was carried out, therefore there are values of the energy consumption missing from April 2016 and forward.

The energy consumption varied a lot during the construction, see the diagram in *Figure 5.6*. As the frame construction started, the energy usage went quite high depending on low temperature outside which put a demand of heating the cabins, containers and the de-humidification of the concrete in the buildings. The de-humidification of the concrete was done by electricity fans and occasionally gas heaters.

The construction crane is another source that consumes a lot of energy, running most of the time during working hours, lifting up heavy components for the buildings. Besides heating and the most of the outdoor lights are set by timers, but must be manually changed due to the gradually changing number of daylight hours.

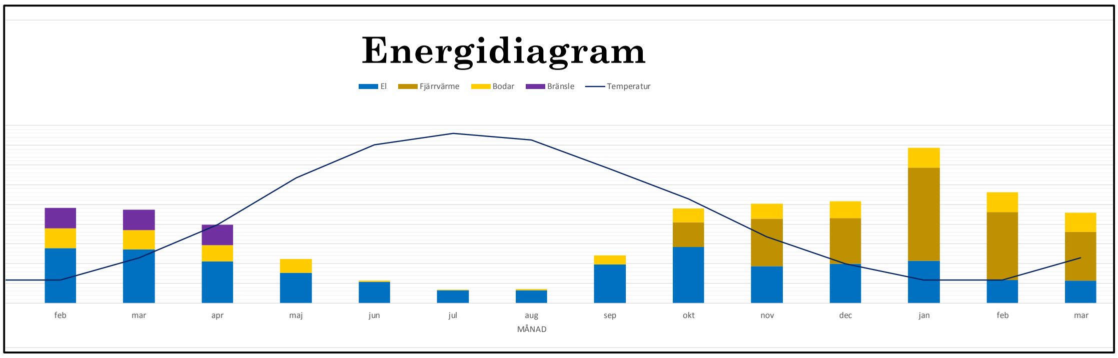


Figure 5.6 The energy consumption for project Landningsbanan. The blue and yellow colour represents the electricity where the yellow is the cabin's estimated contribution. The beige colour is the district heating and the purple represents the fuel. The dark blue curve is the temperature variation.

As the temperature rises and it gets brighter outside, the energy usage decreased, which can be seen in the diagram. The frame was finished in June 2015 and in July it was holiday for the workers, thus there is some activity still on the site. After the holidays the de-humidification of the concrete needed to be completed before the interior work was started, which is the reason of the high need of electricity in September and October, before the district heating was connected. The district heating was switched on as soon as the building was air tight in October (the bars' blue part) and was successively heated during a couple of weeks, which made the energy rise quite much. Note that during this period the outdoor temperature went colder.

This project is the most investigated which is why it is more deeply described than following projects.

5.2.2 All projects in Amhult

Looking at all projects in Amhult together as one big project that started in 2013, the total energy demand per BTA gets higher than Landningsbanan. This big project contains more parts in the construction process than Landningsbanan, which only includes two houses and no ground construction or garage.

The energy went up quite much during winter, see *Figure 5.7*, especially during drying of concrete and when the buildings were heated for the first time. The district heating was turned on in most of the houses as soon as they were airtight. Note that this project has values missing for the last months' energy consumption from April 2016 and forward because data was only collected until April and the project

Landningsbanan was to be finished in June.

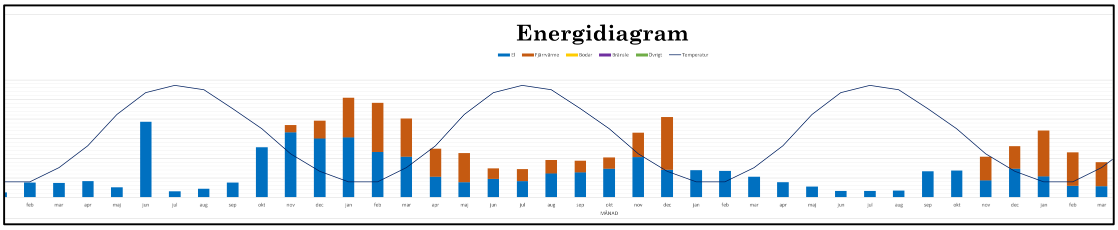


Figure 5.7 The energy consumption for all the big project in Amhult. The blue colour represents the electricity and the orange the district heating. Not the fuel is too small to be recognized from Landningsbanan. The dark blue curve is the temperature variation.

5.2.3 Project Elins Gård

Elins Gård started in 2014 and was erected with prefabricated elements with walls already isolated when delivered, this made the heating capacity low. Without great need of heating the buildings it was seen as both easier and cheaper to only use electrical heating. The frame was constructed during autumn and heated during winter season 2014, which leads to high energy consumption, see *Figure 5.8*.

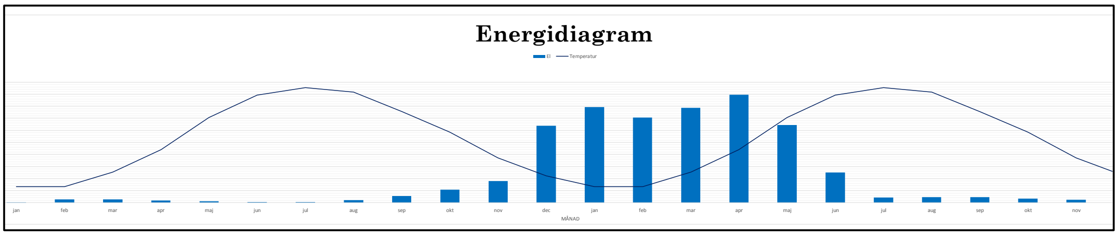


Figure 5.8 The energy consumption for Elins Gård, where the blue colour represents the electricity. The dark blue curve is the temperature variation.

5.2.4 Project Kajen

The building construction of Kajen started in the end of 2013 with ground work and the frame was constructed during the summer and autumn 2014. The heating used to de-humidify the concrete was done by district heating. The heating started in the winter before the house was airtight, which caused the high energy consumption at the beginning of 2015. Note that Kajen is located in a windy place at the coast. This caused a higher energy consumption than in the other projects, see *Figure 5.9*.

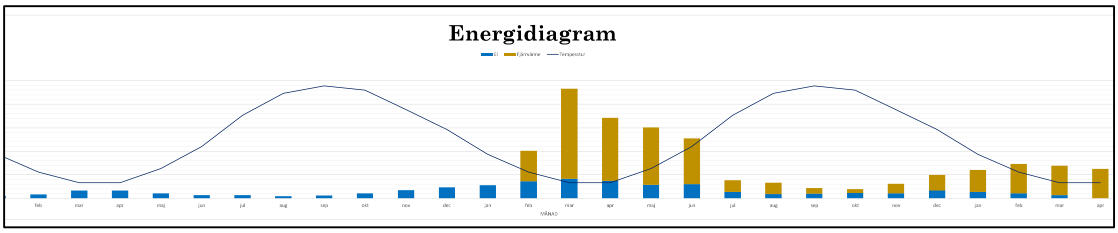


Figure 5.9 The energy consumption for project Kajen. The blue colour represents the electricity and the orange the district heating. The dark blue curve is the temperature variation.

5.2.5 Result of the projects' measuring value

The result of the total energy consumption [kWh] of each project will not be compared since the extent of the buildings are not of the same size. Instead their result can be compared to the different units such as the [kWh/m_{BoA}^2] or by the measuring value. Here the projects' measuring values EM_{share} and $EM_{compare}$, explained in section *5.1.3 The measuring value*, are chosen to be presented. The calculated service life is set to 50 years for all projects and the result is shown in *Table 5.1*.

Table 5.1 Measure values of the studied projects.

Measure value	***Landningsbanan***	***Amhult***	***Elins Gård***	***Kajen***
EM_{share}	4.36%	2.72%	2.57%	3.71%
$EM_{compare}$	4.56%	2.79%	2.63%	3.83%

Note that from section *5.2.1 Project Landningsbanan*, the project Landningsbanan is missing the values of energy from April 2016 and forward, which can be seen as an error. This means furthermore that the big project in Amhult misses those values as well. Three more values were missing, which has therefore been estimated by consider the neighbouring month's values. This means the presented results of the measuring values of both Landningsbanan and Amhult are somewhat lower than the real results.

Another notation is that the temperate area of the project Elins Gård, used to calculate $E_{service\ life}$, was not known. Instead the living area was used, since that area is guaranteed heated. The result of the measuring value can therefore differ a bit from what it should be.

5.3 Hourly energy usage at Landningsbanan

A more detailed result was analyzed through hourly electricity usage collected from Vattenfall. This gave a better picture of how the energy changes throughout a day and for a week. It was seen that the electrical usage went up quite much during working hours compared with non-working hours during the winter period of week 8 in February 2015, when constructing the frame, see the left diagram in *Figure 5.10*. During the later working hours the temperature got higher outside, which decreased the heating demand. In the same time the construction crane and other electrical devices were put in use and lights were turned on. The right diagram in *Figure 5.10* shows the electricity use in August 2015, week 34. At this time the frame was finished and the interior work started, which meant that no construction crane was of any use. Furthermore, the temperature outside went higher and daylight increased, which meant that the need of heating or lights decreased. When comparing the two mentioned weeks it is seen how much more energy that were consumed during the construction in February even after working hours. This shows how much energy it takes only to heat the cabins and the building during the winter.

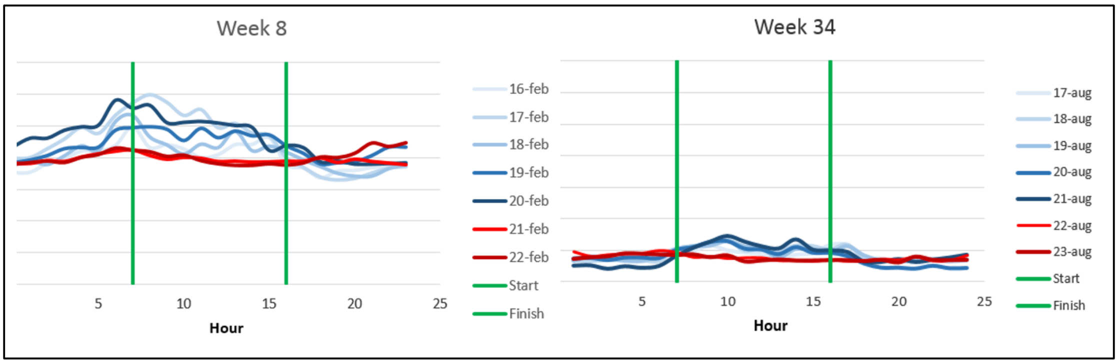


Figure 5.10 Diagrams of the electricity consumption of week 8 (left) and week 34 (right) for project Landningsbanan 2015. The green lines shows the start and end of the working day.

5.4 Survey of Landninsgbanan's site workers' energy knowledge

A questionnaire, see templet in *Appendix D*, was handed out to the workers at Landninsgbanan in April 2016 to see how much they knew and thought of energy in their work. Complementary questions were asked as to gain knowledge of their profession and motivation in their job. Nine workers participated, which including the management at the site, construction workers and subcontractors. They all answered it was either the work itself, colleagues or the salary that keeps them motivated.

The following queries were only energy related questions, where the first one was whether they have gotten information about energy smart behaviour in their work. Only one of the participating, a subcontractor, wrote yes and the other eight wrote no. However, one of the participating from the management left a comment that even if they had not gotten any particular information, they still needed to think of being efficient in how they work.

The next question they answered was what they believed to be the most energy consuming at the site. Out of ten options, it was the construction crane, heating of the containers, cabins and de-humidification of concrete that were chosen mostly. The impact of the workers' behaviour on the energy, was filled in by four of the participated. Two of these, a worker and a subcontractor, believed that this was the second highest reason for the energy consumption. However, the following question of what changes can be done to decrease the consumption, the subcontractors answered with actions which did not affect how they performed their work. The most behaviour related actions did instead come from the management along with other possible actions. A few of the comments made by the participants were to remember to close the door and to turn off electrical things such as the construction crane and elevators.

Regarding heat, suggestions were to decrease the temperature in containers and cabins when it was too high and also use timers more frequently as to not forget to turn off the lightning. For the de-humidification of concrete, the way of how concrete is dehumidified was mentioned by the management to have an impact on the energy and the subcontractors suggested the solution of consider the season of when the dehumidifying should occur.

During the site visits, it was noticed that the workers did not turn off the heating fans in the containers even if it was warm enough outside. The container was not only a place for storing material that is sensitive of low temperature, it was also a place for workers to warm themselves.

6 Discussion

In this chapter will previously presented facts and results be discussed. Firstly, the approach's influence of the outcome of this thesis, followed by ENKLA's usability and the projects' impact on the model. Finally, will the behaviors impact seen in this study briefly be discussed before presenting the conclusions in the next and final chapter.

6.1 The chosen approaches

By going through literature, it was seen that this project would be one of the first studies in the area. This gave the project in the beginning a certain freedom of which approaches to choose. The project's aim has throughout the project been to creating a model suitable for energy mapping. Yet has the picture of the vision of how to get there has changed several times, depending on gained data, information and experience of how the reality looks like.

It might be the case that there are many paths the project could have begun with, were each and every path sooner or later would lead to the same result (other results will not be reflected on since the possibilities are too many). Not taking the approaches onto the right path, or the straightest one from the very beginning, is not seen as a disadvantages at all. Instead have the approaches dissolved boundaries and limits have been discovered along the way which in the end pushed the study at the right direction.

As an example, if the *Energy part table* described in section *4.3.1 Where to collect data* had not been created, the different activities on site might not have been investigated in the same extent. And since the study zoomed in as much as it did with the performed calculations, it revealed and reminded that it was not possible to gain data from the energy usage from workers estimated numbers. And the outcome was the lesson of not intensify any investigation with details before understanding the whole picture of the consumed energy.

6.2 ENKLA

The model will both be a help for Peab to fulfil the energy audit law and to reach their own requirements of increasing energy efficiency through the energy mapping method and energy performance indicators. Since this study is the first made concerning energy mapping Peab's construction sites, it is more or less seen as a pilot project and should therefore be considered as a model under development. Therefore, the proposed model ENKLA is the first draft and is to be discussed in this section.

6.2.1 How the model fulfils the energy audit law and Peab's desires

The energy audit law described in *2.1 Energy audit established in an EU directive* states that a company should present the energy usages' source and activity and thereafter present energy efficient measurements. The model pretty much achieves those demands in the law by presenting the energy source as well as the activity at the site. The model does not however present any energy efficient measurements, but then again by using ENKLA and gain knowledge of where the energy is used and compare it with more projects, measurements can be found.

Worth noting is that the law asks of possible energy efficiency measurements and do not require them to be fulfilled. By using ENKLA it is believed energy efficiency will encourage Peab when seeing the energy costs visually, which might initiate to find measurements reducing the energy costs and by extension the energy usage. Moreover, since Peab wanted help with develop a method to map their energy as mentioned in *2.3.2 Investigation made after the established energy audit law,* and has taken part of this thesis's development, then it is most likely Peab will have use of the proposed model.

6.2.2 ENKLA's design

ENKLA is created with the thought of being easy for anyone to understand and use it without having to take an educating course. Most people at Peab have already several tasks, so the model should not cause a too high workload for the ones that is going to use it either. If it is easy, there is a bigger chance the model will be used.

The many colours in ENKLA are chosen to make it visually and give a feeling of simplicity. The model was first designed to fit one sheet in Excel. But once it was developed with more functions, such as prognosis and inputs, more sheets made it more user friendly.

6.2.3 ENKLA's functions

ENKLA was developed first by trying it on the case study project, thereafter developed by testing it on four more. Necessary functions in the model to make it suitable for the most kinds of house construction projects in Peab has been discovered after each studied project. This way of finding the model's necessary functions successively is believed to make it more functional than if create a so called complete version from the beginning and afterwards implement and use it on projects.

During this study, questions of desired function and measurements were asked around on the site and in the office. The model became developed to meet the wishes, producing different ratios and meeting a greater breadth of work areas, this in hope to both meet the energy audit law requirements as much as being useful for Peab.

After have read SBUF's report and been in contact with Jonas Norrman, the consultant to the SBUF's investigation about the Excel document presented in section 2*.3.1 Investigation before the forthcoming energy audit law*, it was decided to create a model which needed as little administration as possible. The described Excel document also showed that a limited amount of functions was equally important as to provide with an overview of the energy instead of details.

The model is considered to be functional after being tested on a few projects and shown to both the site manager and others within Peab. However, if several more projects had been studied during this thesis, it could be the case to discover that some necessary functions are still missing. This can especially be the case when looking into projects in other parts of Sweden. If the model was to be tested on several projects within the country, feedback could be used to develop ENKLA's functions even further. Then again, when reflecting on the developed method of gain data through bills or measurements and time-plans, which are used in all the Peab

Construction's projects, the model itself seems to include all the functions that can be collected through this method.

6.2.4 The measuring value

The measuring value is meant to provide with results which makes it possible to compare projects with each other in a new way by include the type of constructed building and come up with standard values, see section *5.1.3 The measuring value*. The thought is that the value will consider the buildings characteristics, which affects both the construction sites energy use when erecting the building and the energy consumption in the completed building. The value can be calculated by two suggested equations, which gives approximately the same result. Which to be used is more how the value is chosen to be looked at, either as see the construction site's impact on the project's buildings total service life's energy usage (the erection of the building included) or as to simply compare the construction site with the building's service life (excluding the building's erection).

Whether the value is an effective indicator or not can be discussed further since there are many parameters affecting both a construction and energy consumption in a completed building. This is however, one suggestion believed to be one possible way to start implement the thoughts of how the projects can be compared with each other. Then it is up to Peab to develop it further.

With the ratios Peab asked to be included in ENKLA, they provide with results only concerning the construction sites energy consumption. But when looking at the measuring value, they provide instead with a value which set the construction site's energy usage in relation to the project's buildings. By doing so, knowledge of how much energy is used for a specific type of project can be gained. When learning of a project's energy consumption of a specific kind, then it is believed the reasonable amount of energy consumption can be learned. With that knowledge, then proper measurement suitable for those projects can be made.

But firstly, knowledge of these projects' energy consumption must be gained and this is believed possible with the proposed measuring value.

6.3 When can ENKLA be used and by who

The model itself will provide values which is considered useful for Peab. The question is only *who will be responsible to fill in the necessary data and when?* Even if that is a decision Peab must take, it will be discussed to provide guidance from the gained experience in the matter.

6.3.1 Before a project

In section *3.2.1 Project's process before construction* it was mentioned the site manager makes a construction calculation, where the energy cost is included. By using ENKLA, the model can be used in this phase as to predict the energy consumption and its cost. This prediction can be a template during the construction period to be aware of the real development of the energy consumption and the cost of it.

The one responsible for this should be a person that is involved in this project's phase and preferable the site manager or possibly a new role in Peab for this, depending on the extent the model will be used in the next phases of the project. The model could furthermore be a help for the people who are working within the calculation division by the possibility to advance the skill to predict energy consumption and its costs.

6.3.2 During a project's construction period

The first choice of who should be responsible of ENKLA being used during the construction, is the site manager since this person has got all needed information close to hand and is well-versed in the project. After being in a discussion with one of the involved site managers in this thesis, the manager felt the workload would be too much if given another task to be responsible for. If the model would have been tested throughout a project, the answer might have been different. Still, the same site manager got an introduction to ENKLA and did not see it as complicated tool.

A KMA is another person that is well informed of a project's construction and can act as support for the site manager. This person could therefore be another option of having the responsibility of the model.

A desired function, as already mentioned, would be if the energy data values automatically could be filled in meaning less workload with the model. This is however not a suggestion when believe ENKLA should be tried at first before implement it in an automatic system and feedback must be gained by the one using it.

6.3.3 After a project's construction

After a house construction is finished, ENKLA will map the result of consumed energy to the season and activity along with ratios presented. The responsible for the resulting values should preferable be someone who has or will afterwards keep track of all measured results from projects. This person does not necessary need to be familiar with the model but if not, someone else needs to be able to provide the numbers to the responsible one.

Measurements from many projects can later be used to build up a base of values creating general numbers. These numbers can then be used in later projects in order to predict the energy usage. Perhaps one or a couple of persons could have the responsibility to collect these results.

6.3.4 Potential implementation of ENKLA

Since ENKLA is a first draft of perhaps many more, the suggestion is now that the model is manually filled in and used in the way described in section *6.3 When can ENKLA be used and by who*. When data input has been filled into the model for several projects, then the user might have discovered what is of use and what needs to be reduced and/or developed. Once having received feedback it is believed the model can be implemented in Peab's system where most of the model's functions might be handled automatically.

Since it was desired by a site manager that functions within ENKLA's such as the energy data values could be filled in automatically, it would require further knowledge of how the billing system in the company works and how it could be connected to the model.

6.4 Result from the studied projects

Following section will briefly discuss two parts of the gained results from the projects and their impact on ENKLA.

6.4.1 The frame constructions impact on the energy consumption

More or less all projects' frames were constructed during winter season. This makes them easier to compare but in the same time it would be interesting to see what the difference would have been if at least one of them was constructed during summer season. The most of the energy goes to de-humidify the concrete and heat up the building, a higher temperature outside would probably decrease the demand of heating.

The hourly energy usage of week 8 and 34 in 2015 at project Landningsbanan, see *Figure 5.10*, makes it visible of how much more energy the construction site uses during the cooler months compared with the warm period of the year. During week 8 the frame was constructed and finished before week 34 so the consumption due to activity is not comparable. However, the energy usage after working-hours were still extremely high when comparing week 8 with week 34 and this, as already mentioned, was due to the need of de-humidify the concrete. It would probably not have been that high amount energy consumption if the frame was erected during summer season, which is one proposal to consider in Peab's up-coming projects.

Even if the study of hourly energy usage gave greater understanding of Landningsbanan's energy consumption, it is not included in ENKLA. This is due to it was time consuming just by look into one project. Therefore, it would not be time efficient to suggest Peab to do the same for every project. Besides from the fact the investigation was time consuming, the model is supposed to be built on data easy to collect and provide with an overview of the energy consumption, and not details. More of why details are avoided, at least in the first version of ENKLA, will be discussed in the next section.

6.4.2 Details' impact on the energy consumption

The result from the different projects has its differences, depending on their extent and time of the year of the construction. The layout of the time-plans did also have a great impact of how informative a project's activities were. For instance, it was noticed in one of the studied projects the importance of a house airtightness before turning on any district heating, since this made the energy usage increase much more compared to the other projects. Such information showed how important it was to understand reasons behind the energy consumption. Because of that a column for the airtightness's date was added in ENKLA's input data sheet.

Concerning details specific for a project, it is not believed that they should be searched from the very beginning of a project, since it is more important to understand the overall view of the energy consumption. This was experienced when a method in this thesis was searched; when looking too closely at activities, then it was not possible to understand an activity's energy impact in a bigger perspective. Therefore, it is considered to be a good start of having the overall activities and the energy consumption in ENKLA, before moving into projects' details.

6.5 Behaviour regarding energy

The behaviour and the view regarding the energy is of importance when energy efficient measures are sought for at the construction sites. This due to the measures must be understood and simple enough to follow by the ones who work with the taken measurements. Therefore, it will be discussed how the behaviour was perceived from the site and also a briefly discussion why knowing the affected ones' behaviour are important based on this gained knowledge from this thesis.

6.5.1 Experience from site visits

The focus on Landningsbanan's construction site when visiting was to complete the construction on time since the costs were important as the project needs to be kept within the budget. Because of this, the focus on site was not on the energy consumption, instead the focus was on all costs. Still there were some energy measurements taken which can be seen as energy smart behaviour even though it was the cost that made the effort. One example was the solution of turning on the district heating in the building as soon it was airtight, since it was believed to be cheaper. It was not stated that it was a less energy consuming than the alternative to heat up the building with electrical fans, but the fact that they waited to turn it on until the house was airtight can be considered as an energy smart solution.

It was hard to make measurements concerning the energy consumption while the construction was ongoing since it was all about the planning of a project. The solutions should preferable be done before the construction has started, in one of its earliest stages when planning the project. A standard of how to act and behave on the site to be more energy smart could be integrated to both construction workers and the site management, highlighting how important it is in the society today to keep down the energy use. Then again, the workers were used to execute their work in their own way and if to change that, they must both understand the reason for it and be motivated to change their working patterns.

If the model ENKLA is used, one way to affect the construction workers' behaviour on site could be by show them the diagram with the energy usage each month to make them attentive of both their own and the activities impact on the energy consumption. As already mentioned in *6.2.1 How the model fulfils the energy audit law and Peab's desires*, the site manager will probably be affected by the model to keep the energy costs low. More of how to process the model and behaviour will be discussed briefly in section *6.5.3 The process towards understanding*.

Much convenience behaviour was noticed to be appreciated as well, like the case with the light with movement censors, the workers were happy about these since they often forgot to turn off the lights. Another example is the heating fans in the containers, they were often on even if it was not needed, since the workers think it was pleasant to warm themselves in the heated containers. Thus this was maybe not the best solution of keep the workers warm in an energy efficient point of view.

6.5.2 Result from survey

The result from the questionnaire confirmed the observed behaviour that energy was seen as a side issue to costs. It also showed that none of the workers had got information about energy in their work and that the site management had a better perception about energy than the construction workers. Information about energy usage should definitely be highlighted to the workers more than it is done today.

Concerning the question of what can be improved on site, the site management had a lot to say whereas the construction workers only had a few comments. The reason could be that the site management works with energy consumptions costs and orders from the company. The construction workers perform their tasks in the way they are told to without being involved in energy costs and consumption. To make the construction workers attentive of the energy consumption at the site, the diagram of energy could be presented to them. This might get the workers to start reflecting on the energy usage more and hopefully they will be acting more energy efficient.

The workers answered that the biggest motivation in their work was by the work itself, salary or colleges. Therefore, a reward in money or a team spirit goal/contest could encourage them to act towards an energy smart behaviour. When achieving a measure towards improving the work spirits, it will hopefully result in an improved energy efficiency.

6.5.3 The process towards understanding

To make changes that results in a more energy efficient construction site, the reasons behind those changes must be explained to everyone who are affected. Once understanding *why it is necessary*, it will be easier to actually convince that the changes are necessary. The *why* must be explained in a way the receiver can comprehend, for example by listening or reading, depending on what the receiver in question prefers.

Peab’s office desired an energy mapping model to find energy efficient measurements, this news was not at first seen important at the construction site, where the costs are of greater importance. Therefore, the *why* in this case should instead explain and show the potential of decreasing the costs.

When the *why* is clear for the affected workers, it is important to have a continuous work and/or a dialogue with the changes’ process and development. This is due to the made progress might otherwise be forgotten, as mentioned in SBUF’s report in *2.3.1 Investigation before the forthcoming energy audit law*. This process will most likely affect the behaviour as well, since keeping workers involved might make them keep or increase their effort in their work.

Lastly, to make a change in behaviour to increase energy efficiency, the explanation process and the simplicity of the changes is believed to be the main key, since it is by experience easier to work when actually understand and can grasp the changes. This also concerns the tools used towards energy efficient measurements, where ENKLA is believed to be the start towards energy efficient construction sites.

7 Conclusion

Here are the final of what have already been discussed in the previous chapter in clarification.

7.1 Final remarks

To quote from the introduction, the main purpose of the thesis was to *create a general model of energy mapping suitable for the construction period for Peab Construction*. A model has been developed in a path that from the start was uncertain but when looking back has become explicit when knowing what information there were to collect.

Energy efficiency is a process and before it can be reached, many steps within the process must be taken and determined by Peab. This thesis provides suggestions of how they can start the process at the construction sites. The suggestion is that the company first must learn their energy consumptions on different constructions sites, preferable done by using the thesis proposed model ENKLA. Then it is up to the company how they will use the suggestions and take the following steps towards the goal of energy efficiency.

The proposed model is designed to be easy to use, which open up possibilities for more people to use it and without causing a big workload. ENKLA can be useful before, during and after a project, as a help to predict energy costs, map the energy and find energy efficient measurements. By discovering and investigate projects' energy usage, connections of energy efficient measurements are believed to be found. Predicted values in upcoming projects can be found by thoroughly and constructively view other projects characteristics and measuring values, as total energy use [kWh/m_{BOA}^2] or [kWh/m_{BTA}^2]. The measuring value can be used, but the value might have flaws not thought of. And it is therefore encouraged to investigate and develop the value further, since to include the constructed buildings energy usage is seen as a good alternative way when discussing construction sites' energy consumption.

To conclude where in the studied projects' construction process the most energy were consumed, it was when heat was required. A way of remarkably decrease the energy consumption could be if the frame would be constructed during the summer season instead. Furthermore, it would be a gain if projects' constructions could be scheduled to avoid the cooler months as much as possible.

To improve the workers' energy knowledge on site, the energy question needs to be highlighted to them. This can be done by information orally, written and visually, to make it possible for workers to both ask questions and read it twice. To get a good result the workers need to be motivated in their work as well. Information can easy be overlooked, but if a reward is given after achieved a goal, then the workers might work more efficiently. Since the workers gets motivated by colleges and salary, a common goal of keep down the energy usage with a reward if they succeed could be a motivation. This could also strengthen the team spirit and the reward do not necessary needs to be money, it could be a gift, dinner or activity, depending on their liking.

Lastly, there is much more to do and investigate in the area in order to fulfill the energy audit law and achieve the goal of energy efficiency. Such process takes time and improved routines suitable for the construction site are needed. It is believed that this will be achieved in the future by taking the steps ENKLA provides with. Suggestions of further steps is proposed in next section.

7.2 Further studies

In this project there is a lot more investigations seen as interesting to look further into, but has not been done due to a limit of time. Therefore, the investigations found are instead proposed here below:

The model

- Make the model more general by investigate more projects of different extent, geography and other kind of buildings as schools or offices etc. It could furthermore be developed to be suitable for all kinds of constructions as bridges and roads.
- In addition to the above point, by use the model on several projects in the country, make measure values that can be used as key ratios and be a base to predict energy usage of projects depending on size, geography etc.
- Investigation whether BIM or other system used by Peab can implement the model ENKLA.
- Investigation which connection there are between costs and energy aspects within construction projects, with the purpose to see how the energy can get more in focus than the costs and in the same time make an economic profit.
- If it is possible to connect the consumed energy automatic to the model from the bill system.

Energy efficiency at the construction site

- Procedures on site as how to use heating fans, such as where they should be placed in order to work as optimized as possible.
- This project has only focused on Peab Construction and what energy they pay/are responsible for, but it could be of interest to look into all used energy on the construction site as well as all the transport to the site. This as to see a project's energy consumption.
- How a construction project is affected if the role of KMA or a new role is developed as to be in charge of the energy model.
- Investigation of how the energy usage of a project is affected by the certification system Miljöbyggnad's different levels gold, silver or bronze accordingly.
- Develop an App for the workers on the construction site that will somehow present the energy usage. The App could be a way to work with energy efficiency and increase the awareness of the energy question at the construction site suitable for how the workers perform their job.

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9 Appendices

Appendix A – Construction part table
Appendix B – Energy part table
Appendix C – Frame part table
Appendix D – Questionnaire to the office
Appendix E – Questionnaire to the visited construction site
Appendix F – ENKLA

Appendix A – Construction part table

BYGGDELSTABELL

0	**SAMMANSATTA BYGGDELAR**	00 Samman-satta	01 Demon-tering	02 Rivn. av Inr/Utr	03 Rivn. av Vägg/Bjkl	04 Rivn. Övrigt	05 Rivn. för Hiss/trp	06 Håltagning Förstärkn.	07	08 Provisorier	09
1	**MARK**	10 Samman-satta	11 Röjning Rivning Flyttning	12 Schakt Fyllning	13 Mark-Förstärkn. Dränering	14	15 Ledning Kulvert Tunnlar	16 Vägar Planer	17 Trädgård	18 Mark-utrustn. Stödmur	19
2	**HUSUNDERBYGGNAD**	20 Samman-satta	21	22 Schakt Fyllning	23 Mark-Förstärkn. Dränering	24 Grund-konstr	25 Kulvert Tunnlar	26	27 Platta på mark	28 Huskompl	29
3	**STOMME**	30 Samman-satta	31 Väggar	32 Pelare	33 (Prefab)	34 Bjälklag Balkar	35 (Smide)	36 Trappor Hiss. Schakt	37 Samverk Tak-stomme	38 Huskompl	39
4	**YTTERTAK**	40 Samman-satta	41 Takstomme	42 Taklags-kompl	43 Tak-täckning	44 Takfor & Gavlar	45 Öppnings-kompl Takluckor	46	47 Terasser Altaner	48 Huskompl	49 (Plåt)
5	**FASADER**	50 Samman-satta	51 Stomkompl Utfackninf	52	53 Fasad-beklädnad Ytskikt	54	55 Fönster Dörrar Partier	56 (Utvändiga trappor)	57	58 Huskompl	59
6	**STOMKOMPLETTERING**	60 Samman-satta	61 (Insida yttervägg)	62 Undergolv	63 Innerväggar	64 Innertak	65 Inv dörrar & Partier	66 Invändiga trappor	67	68 Huskompl	69
7	**INV YTSKIKT**	70 Samman-satta	71	72 Ytskikt på golv & trappor	73 Ytskikt vägg	74 Ytskikt tak Undertak	75 (Målning)	76 Vita varor	77 Skåp & Inredn. snickerier	78 Rums-kompl Övrigt	79
8	**INSTALLATIONER**	80 Samman-satta	81	82 Process	83 (Storkök)	84 Sanitet Värme	85 Kyla Luft	86 El	87 Transport	88 Styr	89
9	**GEMENSAMMA ARBETEN**	90 Samman-satta	91 Gemens. arbeten	92	93	94	95	96	97	98	99

Appendix B – Energy part table

KATEGORI	0. SAMMANSATTA BYGGDELAR	1. MARK	2. HUSUNDER-BYGGNAD	3. STOMME	4. YTTERT
BODAR					
Belysning					
Värme					
Vatten					
Apparater					
Säkerhetssystem					
Torkskåp					
Ventilation					
CONTAINER					
Uppvärmning					
Belysning					
TRANSPORT					
Peab					
UE					

5. FASADER	6. STOM-KOMPLETTERING	7. INV. YTSKIKT	8. INSTALLATIONER	9. GEMENSAMMA ARBETEN	SAMMANSTÄLLNING

Appendix C – Frame part table

FYLL I HUR MYCKET DEN DRAR
OCH HUR MÅNGA TIMMAR DEN ANVÄNDS
DETTA ÄR PER PLAN
STOMME - ifylld av Lagbasen Fredrik 10Feb

MOMENT/MASKIN	SLAGBORR	MUTTERKNACK	SKRUVDRAGARE	PAPEGOJA	ROT. LASER	BYGGKRAN	UTTORKNING
FÖRBEREDELSE SKALVÄGGAR (1d)	4 tim	2 tim			2 tim	30 min	
MONTAGE SKALVÄGGAR (1d)		2 tim		5 min		4 tim	
TÄTNING SKALVÄGGAR ~~(1d)~~ (1/2d)	2 tim	1 tim					
MONTAGE UTFACKNINSVÄGGAR (2d)	4 tim	1 tim				8 tim	
MONTAGE VILPLAN + TRAPPA (1d)	30 min	5 min				1 tim	
RIVNING AV STÄMP (24d)							

Appendix D – Questionnaire to the office

Enkätundersökning - Energi på byggarbetsplatsen

Vi är två studenter från Chalmers som gjort denna enkät i syfte att utreda uppfattningen av energi ute på denna byggarbetsplats. Vi är väldigt tacksamma för din medverkan!

Vad är Din arbetsroll i detta projekt?: (Ex. arbetsledare, lagbas, yrkesarbetare)

Ålder?:

Vad för information har Du fått om energismart beteende i ditt arbete? (Svara med ord och/eller meningar)

____

____

Vad får Dig motiverad i Ditt arbete? (Ex arbetskollegor, arbetsuppgifter, mål etc.)

____

____

Rangordna 5 alternativ nedan som tror Du förbrukar mest energi på projektet?:
(Markera den allra största förbrukningen med siffran 1)

☐ Uppvärmningen av bodarna

☐ Uppvärmning av containrarna

☐ Beteende av folk på plats (ex glömmer stänga dörrar, låter maskiner stå på tomgång)

☐ Torkskåp

☐ Byggkran

☐ Bygghiss

☐ Belysning

☐ Handmaskiner

☐ Uppvärmning och uttorkning av betong

☐ Annat:______________________________

Vänd →

Vad i projektet går att påverka eller har påverkats för att få ner energiförbrukningen?:

☐ Uppvärmningen av bodarna.
Kommentar:____

☐ Uppvärmning av containrarna.
Kommentar:____

☐ Beteende av folk på plats (ex glömmer stänga dörrar, låter maskiner stå på tomgång).

Kommentar:____

☐ Torkskåp. *Kommentar*:____

☐ Byggkran. *Kommentar*:____

☐ Bygghiss. *Kommentar*:____

☐ Belysning. *Kommentar*:____

☐ Handmaskiner. K*ommentar*:____

☐ Uppvärmning och uttorkning av betong.

Kommentar:____

Annat. *Kommentar*:____

Tack för din hjälp! ☺

Appendix E – Questionnaire to the visited construction site

Enkät - Presentationen om Energikartläggning i produktion 2016-03-17

Denna enkät är till för att vi som presenterade idag ska få feedback på vår hur användbar/intressant presentationen var för Dig och hur tydliga vi var med vårt budskap om processen bakom framtagandet av vår generella modell. Enkäten består av fyra frågor som uppskattas ta 3-5 minuter.

1. Vad är Din arbetsroll?:____
(T.ex. kalkyl, miljösamordnare m.fl.)

2. Hur berörs du av energikartläggning i Din arbetsroll?
(Förklara kortfattat med antingen enstaka ord eller meningar)

____

____

3. Hur användbar kan dagens presentation vara i Ditt arbete?
(Markera med kryss i den streckade linjen nedan)

1 = Oanvändbar-----------------------------------5-----------------------------------10 =Användbar

Kommentar (frivilligt): ____

4. Någon del i presentationen som behöver förtydligas/saknas enligt Dig för att ge bättre förståelse i vår process? (Markera/ringa in ditt svar)

o Introduktion - Oss, bakgrundsinformation, om projektet

o Tillvägagångssätt - Vår metod/process

o Resultat – Modell i Excel, upptäcker

o Vårt nästa steg – Vad vi har framför oss

o Diskussion – Utformningen av vår modell

o Annat:_______________________________

Tack för Din tid! ☺

Appendix F - ENKLA

F1 - Input data

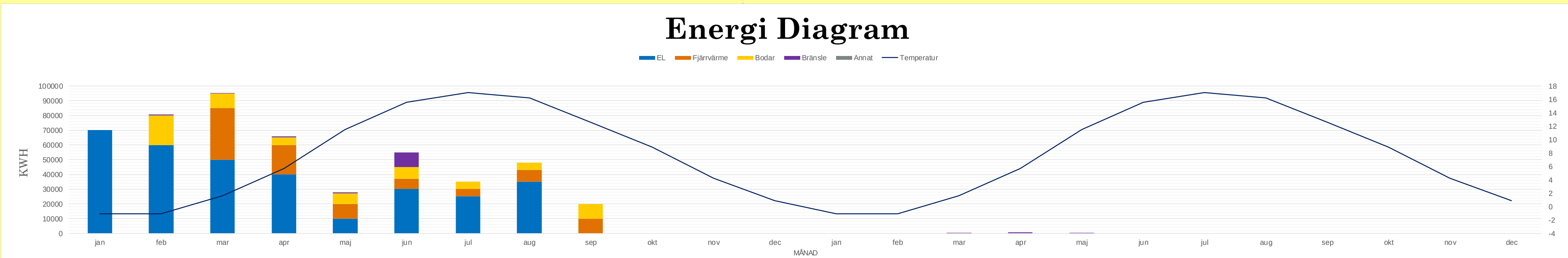
Information om Byggnad							
Namn på projekt	Solhuset	**Stommaterial**	Betong	Ex. Betong, trä	**BTV**	0	m^3
Ort	Göteborg				**BoA**	0	m^2
					BTA	0	m^2
Hyresrätter		**Datum för tätt hus**			**Atemp**	0	m^2
Bostadsrätter							
Antal hus		**Energiberäkning färdig byggnad**		I kWh/kvm BoA, år - uppskattat värde	**Garage**	X	
Antal lägenheter							
Antal våningar		**Livslängd**	50	år			

Period		Klimat	El						Bränsle						Fjärrvärme		Period	Aktivitet					
År	Månad	Medel temp	Tillfällig EL [kWh]	Kostnad tillfällig EL	EL fast [kWh]	Kostnad EL fast	Bodar [kWh]	Övrigt [kWh]	Gasol [kg]	Kostnad Gasol	Diesel [L]	Kostnad Diesel	Bensin [L]	Kostnad Bensin	Fjärrvärme [MWh]	Kostnad Fjärrvärme	Månad						
20XX	jan	-1,1	0		0				0		0		0		0		jan	-	-	-	-	-	-
	feb	-1,1	0		0				0		0		0		0		feb	-	-	-	-	-	-
	mar	1,6	0		0				0		0		0		0		mar	-	-	-	-	-	-
	apr	5,7	0		0				0		0		0		0		apr	-	-	-	-	-	-
	maj	11,5	0		0				0		0		0		0		maj	-	-	-	-	-	-
	jun	15,6	0		0				0		0		0		0		jun	-	-	-	-	-	-
	jul	17	0		0				0		0		0		0		jul	-	-	-	-	-	-
	aug	16,2	0		0				0		0		0		0		aug	-	-	-	-	-	-
	sep	12,6	0		0				0		0		0		0		sep	-	-	-	-	-	-
	okt	8,9	0		0				0		0		0		0		okt	-	-	-	-	-	-
	nov	4,2	0		0				0		0		0		0		nov	-	-	-	-	-	-
	dec	0,9	0		0				0		0		0		0		dec	-	-	-	-	-	-
20XX	jan	-1,1	0		0				0		0		0		0		jan	-	-	-	-	-	-
	feb	-1,1	0		0				0		0		0		0		feb	-	-	-	-	-	-
	mar	1,6	0		0				0		0		0		0		mar	-	-	-	-	-	-
	apr	5,7	0		0				0		0		0		0		apr	-	-	-	-	-	-
	maj	11,5	0		0				0		0		0		0		maj	-	-	-	-	-	-
	jun	15,6	0		0				0		0		0		0		jun	-	-	-	-	-	-
	jul	17	0		0				0		0		0		0		jul	-	-	-	-	-	-
	aug	16,2	0		0				0		0		0		0		aug	-	-	-	-	-	-
	sep	12,6	0		0				0		0		0		0		sep	-	-	-	-	-	-
	okt	8,9	0		0				0		0		0		0		okt	-	-	-	-	-	-
	nov	4,2	0		0				0		0		0		0		nov	-	-	-	-	-	-
	dec	0,9	0		0				0		0		0		0		dec	-	-	-	-	-	-
20XX	jan	-1,1	0		0				0		0		0		0		jan	-	-	-	-	-	-
	feb	-1,1	0		0				0		0		0		0		feb	-	-	-	-	-	-
	mar	1,6	0		0				0		0		0		0		mar	-	-	-	-	-	-
	apr	5,7	0		0				0		0		0		0		apr	-	-	-	-	-	-
	maj	11,5	0		0				0		0		0		0		maj	-	-	-	-	-	-
	jun	15,6	0		0				0		0		0		0		jun	-	-	-	-	-	-
	jul	17	0		0				0		0		0		0		jul	-	-	-	-	-	-
	aug	16,2	0		0				0		0		0		0		aug	-	-	-	-	-	-
	sep	12,6	0		0				0		0		0		0		sep	-	-	-	-	-	-
	okt	8,9	0		0				0		0		0		0		okt	-	-	-	-	-	-
	nov	4,2	0		0				0		0		0		0		nov	-	-	-	-	-	-
	dec	0,9	0		0				0		0		0		0		dec	-	-	-	-	-	-

F2 – Result from input data

PERIOD		KLIMAT	EL				BRÄNSLE		FJÄRRVÄRME		ENERGI						
År	Månad	Medel temp	EL bodar [kWh]	EL övrigt [kWh]	EL tot [kWh]	Kostnad EL	Bränsle tot [kWh]	Kostnad Bränsle	Fjärrvärme [kWh]	Kostnad Fjärrvärme	Energi tot [kWh]	Energi tot/BoA [kWh]	Energi tot/BTA [kWh]	Energi tot/lght [kWh]	Energi tot Atemp [kWh]	Energi tot/BTV [kWh]	Totalkostnad energi
20XX	jan	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
20XX	jan	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
20XX	jan	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
Totaler:			0	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0	0,0	0,0

Mätvärde baserat på energiberäkning i färdig byggnad	
0%	av den totala energi förbrukningen (under produktion och under byggnadens livlängd) går åt i produktionen.

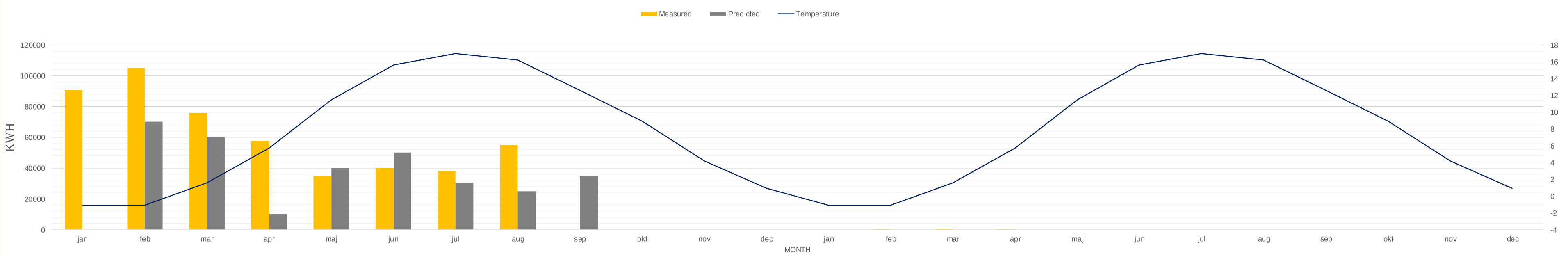


	jan	feb	mar	apr	maj	jun	jul	aug	sep	okt	nov	dec	jan	feb	mar	apr	maj	jun	jul	aug	sep	okt	nov	dec
Aktivitet		Stomme	Stomme	Stomme Tak	Invändigt Tak Fasad	Invändigt Gård Fasad	Semester	Invändigt Gård	Invändigt															

F3 – Comparison of prognosis energy consumption with the result

Period		Klimat	EL								Bränsle								Fjärrvärme		Energi tot [kWh]	Total kostnad energi	Period	Aktivitet	Energi tot/BoA [kWh]	Energi tot/BTA [kWh]	Energi tot/lght [kWh]	Energi tot Atemp [kWh]	Energi tot/BTV [kWh]
År	Månad	Medel temp	Tillfällig EL [kWh]	Kostnad tillfällig EL	EL fast [kWh]	Kostnad EL fast	Bodar [kWh]	Övrigt [kWh]	EL tot [kWh]	Kostnad EL	Gasol [kg]	Kostnad Gasol	Diesel [L]	Kostnad Diesel	Bensin [L]	Kostnad Bensin	Bränsle tot [kWh]	Kostnad Bränsle	Fjärrvärme [MWh]	Kostnad Fjärrvärme			Månad						
20XX	jan	-1,1	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jan		0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	feb		0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	mar		0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	apr		0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	maj		0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jun		0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jul		0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	aug		0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	sep		0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	okt		0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	nov		0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	dec		0,0	0,0	0,0	0,0	0,0
20XX	jan	-1,1	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jan		0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	feb		0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	mar		0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	apr		0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	maj		0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jun		0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jul		0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	aug		0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	sep		0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	okt		0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	nov		0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	dec		0,0	0,0	0,0	0,0	0,0
20XX	jan	-1,1	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jan		0,0	0,0	0,0	0,0	0,0
	feb	-1,1	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	feb		0,0	0,0	0,0	0,0	0,0
	mar	1,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	mar		0,0	0,0	0,0	0,0	0,0
	apr	5,7	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	apr		0,0	0,0	0,0	0,0	0,0
	maj	11,5	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	maj		0,0	0,0	0,0	0,0	0,0
	jun	15,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jun		0,0	0,0	0,0	0,0	0,0
	jul	17	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	jul		0,0	0,0	0,0	0,0	0,0
	aug	16,2	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	aug		0,0	0,0	0,0	0,0	0,0
	sep	12,6	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	sep		0,0	0,0	0,0	0,0	0,0
	okt	8,9	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	okt		0,0	0,0	0,0	0,0	0,0
	nov	4,2	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	nov		0,0	0,0	0,0	0,0	0,0
	dec	0,9	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	dec		0,0	0,0	0,0	0,0	0,0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0			0,0	0,0	0,0	0,0	0,0

Energidiagram med Prognosenergi



	jan	feb	mar	apr	maj	jun	jul	aug	sep	okt	nov	dec	jan	feb	mar	apr	maj	jun	jul	aug	sep	okt	nov	dec
Aktivitet		Stomme	Stomme	Stomme Tak	Invändigt Tak Fasad	Invändigt Gård Fasad	Semester	Invändigt Gård	Invändigt															